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COMPREHENSIVE STUDY OF SPECIFIED AIR POLLUTION SOURCES TO ASSESS THE ECONOMIC IMPACT OF AIR QUALITY STANDARDS

VOLUME I

RESEARCH TRIANGLE INSTITUTE

PREPARED FOR

ENVIRONMENTAL PROTECTION AGENCY

AUGUST 1972

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FINAL REPORT
FR-41U-649
Volume I

COMPREHENSIVE STUDY OF SPECIFIED AIR POLLUTION SOURCES ~~TO~~ ASSESS THE ECONOMIC IMPACT OF AIR QUALITY STANDARDS

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Prepared for

Division of Effects Research
Environmental Protection Agency

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RESEARCH TRIANGLE PARK, NORTH CAROLINA

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ABSTRACT

Estimates are made of the costs of controlling and reducing the emissions of selected pollutants from mobile sources and selected stationary sources within the conterminous United States.

Air pollution control costs for mobile sources are presented on a national basis in terms of unit investment and annual operating and maintenance costs as well as total annual operating and maintenance costs. The analyses cover the estimated emissions and control costs for light-duty and heavy-duty road vehicles only. Mobile-source control costs are given for the model years 1968 through 1977 to show the relative impact of the increasingly more stringent Federal standards. The pollutants from mobile sources selected for analysis are hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x).

Three general classes of stationary sources are considered: Solid waste disposal (open burning and incineration), stationary fuel combustion (heating and power generation), and industrial processes. Industrial processes sources studied are: asphalt batching, cement, coal cleaning, grain plants, gray iron foundries, iron and steel, kraft (sulfate) pulp, lime, nitric acid, petroleum products and storage, petroleum refineries, phosphate, copper, lead, zinc, aluminum, secondary nonferrous metallurgy, and sulfuric acid. Under the assumed implementation plan, stationary source control costs are projected for the five Fiscal Years 1973 through 1977. The stationary source pollutants for which control cost estimates are made are: particulates, sulfur oxides (SO_x), hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxides (NO_x).

An extended analysis is made to determine the economic impact of control costs on each industrial source or group of industrial sources studied. In addition, the aggregate effects of the impact of individual industries upon buyer industries and consumer prices are examined. An examination of the impact on families of different income levels is also provided.

Fiscal Year 1967 was selected as the baseline year so that the estimated costs and reductions in emissions would be those occurring after the passage of the Clean Air Act. Therefore, the costs incurred are assumed to be attributable to the economic impact of program implementation under the Act. All dollar amounts are expressed in 1970 prices and constant 1970 dollars. Emissions and cost estimates are computed through Fiscal Year 1977 using projected growth for source production and capacity. It was assumed that new capacity coming into existence after 1967 would have 1967 control levels, so that control costs attributed to the Clean Air Act would be only those required to go from 1967 control levels to those levels required by the Act.

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Chapter 1: Introduction

This report is submitted in fulfillment of the requirements of the Environmental Protection Agency (EPA) Contract No. 68-02-0088. The research results presented herein were developed in part by the Research Triangle Institute and in part by EPA personnel. They were prepared for the Fourth Annual Report of the Administrator of the Environmental Protection Agency to the Congress of the United States, February 1972. That report, "The Economics of Clean Air", provides estimates of air pollution control costs and economic impact that will result from the implementation of Public Law 91-604, The Clean Air Amendments of 1970. The pertinent section of PL 91-604 reads:

> *"Sec. 312(a) In order to provide the basis for evaluating programs authorized by this Act and the development of new programs and to furnish the Congress with the information necessary for authorization of appropriations by fiscal years beginning after June 30, 1969, the Administrator, in cooperation with State, interstate, and local air pollution control agencies, shall make a detailed estimate of the cost of carrying out the provisions of this Act; a comprehensive study of the cost of program implementation by affected units of government; and a comprehensive study of the economic impact of air quality standards on the Nation's industries, communities, and other contributing sources of pollution, including an analysis of the national requirements for and the cost of controlling emissions to attain such standards of air quality as may be established pursuant to this Act or applicable State law. The Administrator shall submit such detailed estimate and the results of such comprehensive study of cost for the five-year period beginning July 1, 1969, and the results of such other studies, to the Congress not later than January 10, 1969, and shall submit a re-evaluation of such estimate and studies annually thereafter."*

II. SCOPE OF RESEARCH

Estimates have been provided of emissions, control costs, and economic impact on a national basis for mobile sources, solid waste disposal, stationary fuel combustion, and 19 industrial process sources. Analysis of mobile sources was limited to automobiles, and on the highway trucks, and buses. The analysis of solid waste disposal covered open burning and incineration. Stationary fuel combustion sources were divided into residential heating, intermediate boilers (commercial and industrial heating), and steam-electric power plants. The 19 industrial process sources covered are: asphalt batching, cement, coal cleaning, grain handling, feed milling, gray iron foundries, iron and steel, kraft (sulfate) pulp, lime, nitric acid, petroleum products and storage, petroleum refineries, phosphate, primary nonferrous metallurgy (copper, lead, zinc, aluminum), secondary nonferrous metallurgy, and sulfuric acid.

Emission and cost estimates were made covering particulates, sulfur oxides, carbon monoxide, and hydrocarbon pollutant emissions from all sources. In addition, emission and cost estimates related to oxides of nitrogen were made for mobile sources and for nitric acid plants.

This report includes the emission, cost, and economic impact analyses published in "The Economics of Clean Air" and provides, in addition, discussion of the technical analyses underlying the estimates and pertinent technical data and references as appropriate.

III. LIMITATIONS OF THE ANALYSIS

The quality of the analysis that supports the annual report on "The Economics of Clean Air" has improves significantly each year as new data are added and the results of many private and federally-funded studies are incorporated. There are, however, still significant gaps in the available data that have limited the precision and coverage of this report. Many of these are noted specifically in the analyses of individual sources in later chapters of this report. Only the general study limitations are discussed in this section.

The analysis of mobile sources is based in part on estimates of the existing vehicle population and projections of the distribution of vehicles for future years. Neither the current population nor expected future life can be determined with complete accuracy. Vehicle use patterns are not known precisely and, since they determine emissions, in part, this reduces the accuracy of emission estimates. Similarly, emission rates are variable, depending on a number of factors, and these data are quite limited. Finally, control system configurations, efficiencies, and costs are still under development and manufacturers are able to provide only limited estimates of these factors. There is, as a result, considerable difference of opinion over the accuracy of all estimates of mobile source control, including that contained in this study.

In analyzing stationary source controls and their economic impact, RTI and EPA have utilized all the published and unpublished data available. It has not been possible, however, to identify the location, capacity, production, process units, and present control levels of all plants in all industries. Wherever gaps were present in these data, indirect estimating techniques had to be employed. These included the use of averages, model plants, and "best estimates" provided by industry experts.

Analysis of the economic impact on specific industries was limited by the fact that data were generally not available on the revenue and profit attributable directly to individual plants, processes, and products for most of the firms involved. Information was also lacking on the elasticity of demand in product markets, making it necessary to utilize qualitative judgments of probable impacts on market prices. This was particularly difficult when some sectors of an industry faced costs differing from those affecting other sectors.

The macroeconomic analysis is based on the use of input-output analysis with all the limitations inherent in that technique. These include especially the assumptions of constant technology and unchanging trade relationships.

Chapter 2: Summary--Economic Cost and Impact

The detailed analyses of mobile and stationary source control costs and economic impacts on industries are given in Chapters 3 and 4. 4. The cumulative effect of these upon the aggregate economy is discussed in Chapter 5. These materials are summarized here to indicate the general approach and methodology used and to provide an overview of the study.

I. METHODS OF COST ESTIMATION AND IMPACT ANALYSIS

A. Control costs are estimated in terms of the initial investment required to establish control and the continuing annual expenses related to that investment. The investment cost is the total expense of purchasing and installing control equipment. The annual cost is the ultimate yearly charge for capital-related costs (interest on the investment funds, property taxes where applicable, insurance premiums, and depreciation charges) plus operating (labor, utilities, and supplies) and maintenance costs. All costs are given in 1970 dollars.

Fiscal Year 1967 (model year 1967 in the case of motor vehicles) was used as a baseline year. Control costs were combined for two groups of stationary sources: those that were operating when the November 1967 amendments to the Clean Air Act became law and newer sources that have begun operations since that time or are expected to do so by June 30, 1977. This latter group was calculated on the basis of industry production and capacity data as well as relevant information on industry growth patterns. Control costs for mobile sources are estimated for new cars starting with model year 1967 and including model year 1977.

In general, control costs were estimated by calculating the expenditure required to increase the levels of emission control from an assumed baseline level to the level required for compliance with the selected emission control regulations by adding or upgrading control equipment. This approach is based on the premise that the costs properly attributable to the implementation of the Clean Air Act, are those incurred in reaching control levels not commonly being achieved at the time of the passage of the 1967 amendments to the Act.

The number and type of installations currently controlling pollutants, the level of efficiency each is achieving, their capacity, and other characteristics are bases for determining the extent and types of control methods needed to meet the selected standards. Assumptions, including the set of control regulations, are identified in this report in the discussion of each emission source.

In addition, this report presents estimates of the impact of industry costs both on the industries themselves, in terms of profits and business operation, and on the consumers of the products produced. Price increases are developed and their impact on the final purchasers of the Nation's output are estimated. Although the primary focus is on prices to individual consumers, investment, Government, and export prices are also examined and impact estimated.

II. SOURCES OF DATA

A wide variety of data sources was used in the preparation of this analysis. The lists of references found at the end of various sections and subsections of this report indicate the primary materials used for specific analyses. General data sources and materials used throughout the study included industry data from the financial and industrial reports issued by Dun and Bradstreet, Standard and Poor, and Moody, from the Bureau of the Census and the Internal Revenue Service and control and cost data from the reports of the Environmental Protection Agency and studies reported by the International Gas Cleaning Institute. In addition, a large number of technical and business journals were reviewed for specific data and for acquiring a general understanding of the industries covered and the appropriate control systems.

III. SUMMARY OF COSTS AND IMPACTS

A private outlay of about $35 billion is estimated over the period Fiscal Years 1973-1977 to implement the stationary and mobile source emissions reductions postulated in this study. Mobile source controls are projected to cost $24.7 billion for the 1973-1977 model years ($26.9 billion for the 1968-1977 model years). The investment cost of controlling the stationary source types considered in this report is projected to be $10.1 billion. All cost estimates are given in 1970 dollars.

The Environmental Protection Agency air program budgets for Fiscal Years 1972 and 1973 are estimated to be $134.2 million and $158.7 million, respectively. From these totals, grants to State and local agencies during those two years are expected to be, respectively, $42.9 million and $51.5 million. State and local funding for those years is estimated at $56.8 million and $64.5 million, respectively.

In last year's report a total private outlay of about $10.5 billion was estimated for mobile ($4 billion) and stationary source ($6.5 billion) controls for the 5-year period, Fiscal Years 1972-76. These amounts differ widely from the corresponding totals in this report for the following reasons:

> The $3.6 billion increase to $10.1 billion in the 5-year investment cost of controlling the emissions of the stationary source types studied directly reflects increasing the number of plants in each source type to the national total in this report. This is in contrast to the number of plants existing only in the 298 metropolitan regions studied in last year's report. This extension is compatible with the national scope of the 1970 Clean Air Act Amendments, but does not recognize possible differences in emission control levels sufficient to achieve national primary and secondary ambient air quality standards under abatement implementation plans submitted by States pursuant to Section 110 of the Act.
>
> The $20.7 billion increase to $24.7 billion in the 5-year cost of mobile source controls in this report results from the higher expected cost of emission controls to meet the more stringent automobile emission standards mandated by the 1970 Clean Air Act Amendments for implementation in 1975 and 1976. Specifically, Alternative 1 in Table 3-3 is assumed in the cost analysis as the combination of emission controls adopted by automobile manufacturers. Under this assumption, for example, the FY 1976 mobile source control costs in this report (Table 3-3) amount to $7.16 billion while the costs reported last year for 1976 were $3.94 billion.

Table 2-1 compares the source emission reductions achieved in FY 1977 under the emission standards assumed in Appendix I with potential emissions from these source types if no controls were implemented beyond those normally found in practice.

Comparison with last year's report will show that four industry types (brick and tile, elemental phosphorus, rubber tires, and varnish) were not included in this report. The brick and tile, and the elemental phosphorus industries are mainly sources of fluoride, for which no new information is available to justify further reporting at this time. A reexamination of last year's data on the rubber tire industry indicates that too little quantitative information is available from which to generate reliable cost estimates. The varnish industry is not included this year because information shows it to be a minor and disappearing source of HC due to declining market conditions.

Also given in Table 2-1 are estimated pollutant emissions in 1977 from all other industrial and miscellaneous classes for which controls were not studied in this report. The "Industries Not Studied" group in Table 2-1 accounts nationally for about 28 percent of the particulates, 3 percent of the SO_x, 4.5 percent of the CO, 4 percent of the HC, and a negligible amount of NO_x. These excluded industries account for the following approximate amounts of the 10.2 million tons of particulates attributed to them in Table 2-1:

• Crushed stone, sand, and gravel .	5.8	million	tons
• Other steel processes	1.0	"	"
• Clay products	0.6	"	"
• Lime crushing and screening . . .	0.3	"	"
• Ferroalloys	0.2	"	"
• Forest products	0.2	"	"
• Carbon black	0.1	"	"
Subtotal	8.2	"	"
Other small sources	2.0	"	"
Total	10.2	million	tons

TABLE 2-1. NATIONAL EMISSION REDUCTIONS AND COSTS UNDER ASSUMED STANDARDS FOR FISCAL YEAR 1977

(COST IN 1970 DOLLARS)[1]

Source Class Type	Emission Level without further control[2] (Thousands of Tons Per Year)					Emission Reductions and Cost Under Assumed Standards						
						Decrease of Emission Level (Percent)[2]					Total Control Cost (Millions of Dollars in FY 77)[3]	
	Part	SO_x	CO	HC	NO_x	Part	SO_x	CO	HC	NO_x	Investment	Annual
Mobile Sources[4]	450	1,490	165,000	28,000	9,900	[4]	[4]	66	72	44	$ [7]	$ 8,385[7]
Solid Waste Disposal	1,830	260	6,720	2,530	510	96	0	92	86	0	472	224
Stationary Fuel Combustion:												
Small & intermediate boilers	2,330	7,660	--	--	4,800	84	83	--	--	0	879	1,116
Steam-electric power	5,600	27,600	--	--	6,000	49	90	--	--	0	4,660	1,360
TOTAL	7,930	35,260	--	--	10,800	72	88	--	--	0	$ 5,539	$ 2,476
Industrial Process Studied:												
Asphalt Batching	403	--	--	--	--	86	--	--	--	--	$ 272	$ 63
Cement	908	--	--	--	--	93	--	--	--	--	89	35
Coal Cleaning	342	--	--	--	--	97	--	--	--	--	21	9
Grain Plants: Handling	1,430	--	--	--	--	93	--	--	--	--	395	83
Feed	362	--	--	--	--	94	--	--	--	--	19	4
Gray Iron Foundries	260	--	3,800	--	--	88	--	94	--	--	348	126
Iron and Steel	1,991	--	--	--	--	96	--	--	--	--	841	306
Kraft (Sulfate) Pulp	536	--	--	--	--	85	--	--	--	--	132	40
Lime	609	--	--	--	--	94	--	--	--	--	29	7
Nitric Acid	--	--	--	--	230	--	--	--	--	89	37	14
Petroleum Products & Storage	--	--	--	1,349	--	--	--	--	78	--	378	73
Petroleum Refineries	241	3,010	12,100	197	--	59	99	99	94	--		
Phosphate	350	--	--	--	--	54	--	--	--	--	31	15
Primary Nonferrous Metallurgy:												
Copper	314	3,335	--	--	--	9	84	--	--	--	313	100
Lead	39	213	--	--	--	33	86	--	--	--	65	16
Zinc	71	555	--	--	--	0	75	--	--	--	41	18
Aluminum	49	--	--	--	--	89	--	--	--	--	923	256
Secondary Nonferrous Metallurgy	34	--	--	--	--	83	--	--	--	--	32	9
Sulfuric Acid	38	920	--	--	--	74	81	--	--	--	169	39
TOTAL	7,977	8,033	15,900	1,546	230	86	89	98	80	89	$ 4,135	$ 1,213
Industries Not Studied	10,150	1,530	9,750	1,610	--	0	0	0	0	0	0	0
Miscellaneous Sources Not Studied [5]	7,940	280	19,740	7,750	5,250	0	0	0	0	0	0	0
National Total [6]	36,280	46,850	217,110	41,440	26,690	39	81	57	17	60	$10,146	$12,298

TABLE 2-1. - FOOTNOTES

1/ Assumed standards given in Appendix I. Blanks in the table indicate that emission levels meet applicable regulations or that emissions are negligible or do not exist.

2/ Emission abbreviations are: particulates (Part), sulfur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x).

3/ Projected costs are the initial investment expenditures for purchasing and installing control equipment (total investment) and the continuing annual costs for interest, property taxes, insurance, depreciation, etc., and for operating and maintaining of equipment (ultimate annual cost). Cost of government programs is not included.

4/ Includes light-duty and heavy-duty road vehicles only. Control of particulates and sulfur oxides from mobile sources was not considered in this study.

5/ Forest fires, structural fires, solvent evaporation, agriculture burning, natural gas production and transmission, coal refining, etc.

6/ To nearest 10,000 tons.

7/ All mobile source emission control investment costs are assumed to be expended in FY 1977. Annual costs are based on Alternative 1 in Table 3-3 for meeting 1975 and 1976 vehicle emission standards.

The "Miscellaneous Sources Not Studied" account nationally for about 22 percent of the particulate emissions. These come mainly from forest fires and structural fires and are not subject to the same kind of control programs applicable to the other sources discussed above.

Some or all of the controllable sources of emissions mentioned above may be subject to control under abatement implementation plans developed by the States to meet the national ambient air quality standards. The inclusion or exclusion of source types in this report is not to be construed as a recommendation for inclusion or exclusion of these source types in State plans submitted to EPA for approval under Section 110 of the Act.

The FY 1977 costs of the control technology likely to be used by the sources studied are given both as total investment in that year (purchase plus installation cost) and as annualized cost (capital charges plus operating and maintenance costs). Federal, State and local subsidies (accelerated amortization, investment tax credit, etc.) have not been considered in calculating private industrial emission control costs.

The aggregate price impact of private investment in air pollution control is projected to result in less than a one percent cumulative increase in consumer prices through 1977, with over half of the increase caused by a 10 percent rise in the price of new automobiles. Other key price increases projected are 4 percent for electric power, and 2.5 percent for iron and steel, cement, and sulfuric acid. The remaining projected industrial price increases are 1.5 percent or less.

An examination of the impact on families of different income levels indicates that middle income groups would be affected relatively more than low or high income groups.

New construction is the investment activity most heavily affected by projected price increases. New public utility construction is affected most because of increased prices for copper, electricity, iron and steel, iron castings, and passenger cars and trucks. Higher passenger car and truck prices will increase investment costs for transportation. Projected price increases will also raise prices for machinery, electric industrial equipment and apparatus, and communications equipment.

Export prices for agriculture products, chemicals and chemical products, and passenger cars and trucks would increase, but the net impact on exports and balance of payments is difficult to predict because the relationship of demand to projected price increases is unknown.

Thus, the net adverse economic impact of the stipulated air pollution controls is projected to be small. The economic effects of the concurrent costs for water pollution control, solid waste disposal, noise abatement, and esthetic improvements, will be considered in a separate EPA report now in preparation.

A. Mobile Sources

National standards are in effect or anticipated for emissions of hydrocarbons, carbon monoxide, and nitrogen oxides for motor vehicles. Particulates are not considered this year on the assumption that the coming widespread use of unleaded or low lead gasoline will eliminate the major motor vehicle particulate source.

The cost of controlling motor vehicle emissions for Fiscal Years 1968 through 1977 totals almost $26.9 billion (Table 3-8). Tables 3-5 and 3-6 exhibit the additions to annual operation cost that can be expected because of design changes and equipment for the control of air pollution.

Adverse emissions will decrease substantially through model year 1977. Hydrocarbon emissions will be reduced to about 28 percent of the potential emissions of that year. Carbon monoxide will be about 35 percent of its potential and nitrogen oxides down to about 56 percent.

In addition to reduced emissions, some reductions in maintenance costs can be expected as a result of control measures. The useful lives of some components will be increased and the intervals between engine oil changes and tune-ups extended. Engine reliability will be improved. The net increase in operating and maintenance costs by 1977 is expected to be about $65 for light-duty vehicles and $100 to $300 for heavy-duty vehicles. The full cost of air pollution control equipment on automobiles will be passed on to consumers. This price increase is estimated to be about 10 percent or $350 by 1977.

B, Stationary Sources

The economic impact of the control of air pollution from stationary sources has been examined for solid waste disposal, stationary fuel combustion, and industrial processes. The examination covered 22 source categories, deriving information that was aggregated in Chapter 5 to find the effect of control costs on the U.S. economy.

If the solid waste disposal practices existing in 1967 continued unchanged through Fiscal Year 1977, the projected level of emissions will reach 1,830 million tons of particulates, 2.53 million tons of hydrocarbons, and 6.72 million tons of carbon monoxide. By eliminating all open burning by municipal and private disposal agencies and equipping all municipal incinerators and 80 percent of the large commercial incinerators with electrostatic precipitators, scrubbers, and other control devices, 1977 emissions will be reduced to 65,000 tons of particulates, 360,000 tons of hydrocarbons, and 512,000 tons of carbon monoxide. About 25 percent of the waste collected by municipal agencies and 75 percent of that collected by private agencies will be disposed of by means requiring air pollution controls. This will require an investment of $472 million and annualized costs of $224 million.

Control of emissions from fuel combustion in small and intermediate boilers and steam-electric power plants will require a total investment of $5,539 million by the end of Fiscal Year 1977. The associated annualized cost will be $2,476 million. Particulates and sulfur oxides will be reduced by 72 percent and 88 percent respectively for steam-electric power plants. In this category steam-electric plants will require the major investment, $4,660 million with an annualized cost of $1,360 million. This will result in a rate increase for electrical power of about 4 percent which will be diffused in the economy and have significant effect on other price patterns in only a few cases.

The total investment expenditure for the 15 industrial sources at the end of FY 1977 will be $4,135 million and the associated annualized cost will be

$1,213 million. This covers the cost of controlling five pollutants: particulates, sulfur oxides, carbon monoxide, hydrocarbons, and nitrogen oxides.

Price increases will average about 7 percent for primary nonferrous metallurgy, about 10 percent for automobiles, about 4 percent for electrical power, and about 2.5 percent for iron and steel, cement, and sulfuric acid. Other price increases are 1.5 percent or less.

C. Aggregate Economic Impact

This chapter examines the impact of industry cost and price increases on the final purchasers of the Nation's output. The focus is primarily on consumer prices, but the impact on investments, Government, and exports is also examined.

Consumer prices in 1977 are projected to increase by about 0.72 percent and employment will show no appreciable change as a result of the cost of controlling air pollution. Well over half of this increase results from the projected 10 percent price increase for new automobiles. Other key price increases having a significant impact are those for electrical power, aluminum, iron and steel products, and iron foundry products.

An examination of the impact on families of different income levels indicates that middle and upper income groups would be affected more than lower or high income groups.

New construction is the investment activity most heavily affected by projected price increases. New public utility construction is affected most, because of increased prices for copper, electricity, iron and steel, iron castings and passenger cars and trucks. Increased passenger car and truck prices will increase investment costs for transportation and warehousing. Projected price increases will also increase prices for machinery, electric industrial equipment and apparatus, and communications equipment.

The impact of price increases on Government services is projected to be quite small because the largest share of Government cost is for employee compensation.

The net impact on exports and balance of payments is difficult to predict because the size of the response of the quantity demanded to the projected price increase is unknown. Export prices for agriculture products, chemicals and chemical products, and passenger cars and trucks would increase.

Chapter 3: Mobile Sources

I. INTRODUCTION

This chapter analyzes the cost of complying with current and projected Federal standards for motor vehicle air pollution emissions and presents estimates of the cost to purchasers and users of motor vehicles due to air pollution control for Fiscal years 1967-77. The analysis covers only automobiles and on-the-highway trucks and buses. Other engines and transportation forms are excluded. The cost estimates are based on current and anticipated standards and other available data as of August 15, 1971.[1/] The standards cover or will cover emissions of hydrocarbons, carbon monoxide, and nitrogen oxides from motor vehicles. Smoke for diesel vehicles is also covered by standards.

This chapter compares projected emissions under the anticipated standards with potential emissions which would be expected if no standards were in effect. Comparison is also made of emissions under standards with 1967 conditions. The estimates and projections of emissions contained in this chapter are different from previously published estimates due to changes resulting from the Clean Air Act Amendments of 1970. The costs of meeting the standards are expressed in terms of additional initial costs to vehicle consumers, increases in operating and maintenance costs, and an annualized combination of increased operating and maintenance costs. Only costs directly associated with control of vehicular emissions are included. Costs or price increases from controls on supplier industries, such as steelmaking, are considered in Chapter 5. Costs in the form of Government programs are discussed in Chapter 2. Costs due to use of unleaded gasoline have been included in total costs presented in this chapter.

[1/] EPA announced on February 11, 1972, that the 1973 heavy-duty vehicle standards proposed on October 5, 1971, were being withdrawn and that new standards would be imposed for the 1974 model year instead. There was insufficient time to change this report to reflect either this new effective date or likely changes in the technical nature of the control requirements.

II. EMISSIONS

A. Nature and Sources of Emissions

Motor vehicles are a major source of air pollution in the United States. The four major pollutants from motor vehicles are hydrocarbons (HC), carbon monoxide (CO), nitrogen oxides (NO_x), and particulate matter. In 1967, motor vehicles accounted for approximately one-half of the hydrocarbon and two-thirds of the carbon monoxide emissions to the atmosphere in the United States. Motor vehicles also contributed about one-third of the nitrogen oxides and nine-tenths of the lead-bearing particulate matter to the total national emissions of these pollutants.

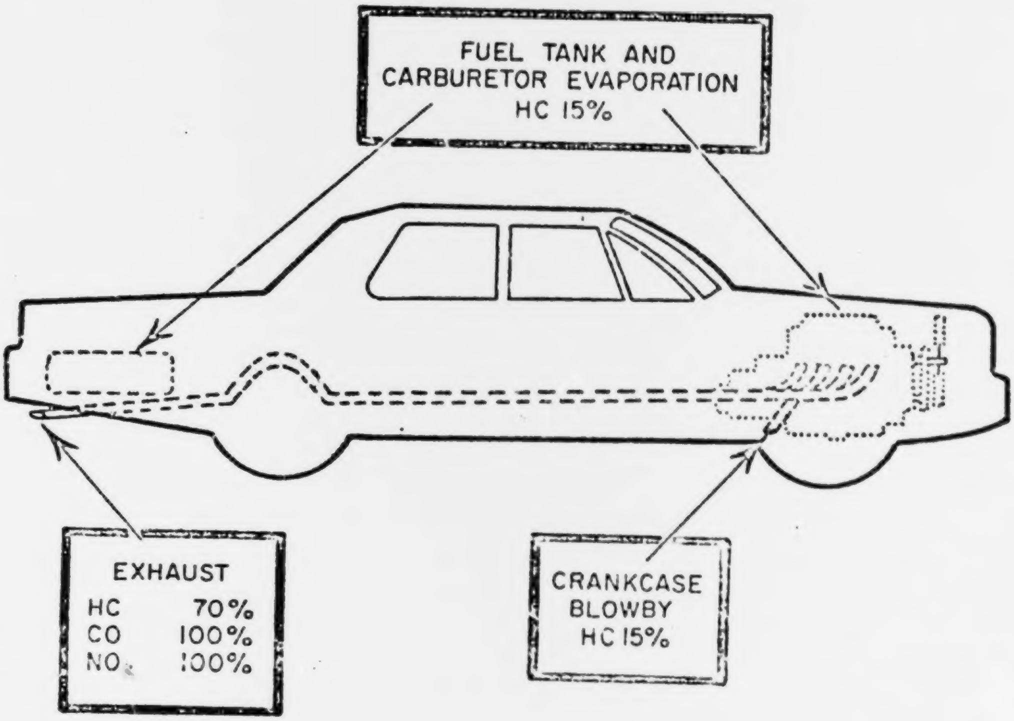
FUEL TANK AND
CARBURETOR EVAPORATION
HC 15%
EXHAUST
HC 70%
CO 100%
NO 100%
CRANKCASE
BLOWBY
HC 15%

Figure 3-1. Approximate Distribution of Emissions by Source for a Vehicle not Equipped with any Emission Control Systems.

Emissions from gasoline-powered vehicles occur in several ways. Hydrocarbon emissions from evaporation in fuel tanks and carburetors, blowby, and leakage in engine crankcases are present in exhaust gases. Incomplete combustion is the source of hydrocarbons in the exhaust gases and also produces carbon monoxide. In the internal combustion engine some of the atmospheric oxygen and nitrogen combine to form nitrogen oxides which are emitted in the exhaust. Unfortunately, conditions which favor more complete and efficient combustion (thereby reducing exhaust emissions of hydrocarbons and carbon monoxide) tend to increase the formation of nitrogen oxides. Figure 3-1 illustrates the sources and approximate relation of these emissions.

The emissions from diesel engines are principally nitrogen oxides and smoke. The nitrogen oxides are a natural result of the high combustion temperatures in diesels. Diesel engine smoke consists almost entirely of small carbon particles. Based on present knowledge, the total amount of emissions from diesel engines represents much less of an environmental problem than that from gasoline engines. Diesel smoke, however, may be highly visible and produce soiling because of its sooty nature. For these reasons (and because of odors), public attention is drawn to diesels.

B. Emission Levels With and Without Standards

As has been previously noted, changes have been made in the standards and measurement techniques in effect for Fiscal years 1968-77. In the emission estimates reported herein, corrections have been made so that the data are comparable for the entire period.

Crankcase emission controls were already standard on new automobiles at the beginning of the time frame considered here. The crankcase contributions of the older vehicles which are not equipped with blowby control devices are included in the emission estimates presented here.

1. Potential Emissions without Standards

Table 3-1 gives the expected number of automobiles, trucks, and buses in use for Fiscal years 1967-77. This table indicates the potential problem which could be expected if no control regulations or standards were in effect. The total number of vehicles in use shows an expected growth of approximately 40 percent. Total annual emissions would increase approximately the same percentage without controls.

In Table 3-1, the vehicle populations have been projected on

TABLE 3-1. - GROWTH OF VEHICLE POPULATION 1967-77

Fiscal Year	Millions of Vehicles					Percent Controlled		
	Gasoline-Powered			Diesel-Powered		Gasoline		Diesel
	Autos and Light-Duty Trucks	Heavy-Duty Trucks	Buses	Heavy-Duty Trucks	Buses	Autos and Light-Duty Trucks	Trucks and Buses	Trucks and Buses
1967	81.8	5.6	0.28	0.46	0.06	-	-	-
1968	84.6	6.0	0.29	0.50	0.06	9.0	-	-
1969	88.1	6.3	0.30	0.55	0.07	20.5	-	-
1970	91.1	6.6	0.30	0.60	0.07	31.5	7.5	-[1]
1971	93.8	6.8	0.31	0.65	0.07	42.0	17.0	-
1972	96.8	7.1	0.32	0.70	0.07	52.0	26.0	-
1973	100.1	7.5	0.33	0.77	0.07	61.0	34.5	-
1974	103.5	7.8	0.34	0.84	0.07	69.0	42.5	-
1975	106.9	8.3	0.35	0.91	0.08	76.0	49.5	7.5[2]
1976	110.5	8.7	0.36	0.99	0.08	82.0	55.5	17.0
1977	114.2	9.1	0.37	1.08	0.08	87.0	61.0	26.0

[1] Smoke control began in 1970 for diesels. Since some prior model vehicles meet standards with careful operation (and perhaps in-service modifications) percent controlled is applied only to gaseous emissions.

[2] Assume same age distribution for diesels as for HD gasoline trucks.

the basis of the best information on the number of vehicles actually in use rather than on the number of vehicle registrations. This method eliminates multiple counting of some vehicles due to redundant registration transactions. Vehicle growth has been based on population projections of the Census Bureau and historical trends in growth of total vehicle numbers and vehicles per capita.

The vehicles shown in Table 3-1 are divided into two basic categories; the first comprises automobiles and light-duty trucks. Light-duty (LD) trucks are 6,000 pounds or less in gross vehicle weight (GVW), and the second category, heavy-duty (HD) vehicles, consists of those over 6,000 pounds GVW. The vehicle data shown include diesel trucks and buses of the gasoline and diesel varieties. Based on the best data available, buses (of all types) and diesel trucks constitute a small fraction of the total vehicle population. Diesel trucks contribute less than 4 percent of the Nation's annual vehicle travel mileage. Buses contribute less than 0.5 percent of the annual vehicle miles. Since these small percentages are difficult to discern in effects on national emissions and control costs within the accuracy of available data, buses are included with HD trucks under the proper engine categories.

2. Emission Levels with Standards in Effect

Table 3-2 illustrates the effects of anticipated controls on emissions for Fiscal years 1967-77. In making the projections shown in Table 3-2, current and anticipated standards detailed in Appendix I were used. These standards either have been promulgated or are under consideration by EPA. The anticipated 1975-77 standards for heavy-duty vehicles are still under study and development. It has been assumed that all standards will be met by FY 1977.

Table 3-2 shows projected emissions as percentages of the uncontrolled potentials. Approximately 82 percent of the motor vehicles in use should be controlled to some degree by FY 1977. In projecting emissions and the percentages of vehicles under control, the age distribution of vehicles in use has been considered with older vehicles being removed from service and new vehicles being added with time. Age and use distribution within the vehicle population are based on 1969 data. It is assumed that a comparable distribution will hold through FY 1977.

The emissions level of nitrogen oxides with controls is expected to rise above the uncontrolled level for a period of several years. This is due to the fact that the controls for hydrocarbons and carbon monoxide, which were implemented earlier than those for nitrogen oxides, tended to produce an increase in nitrogen oxides. This effect has been partially offset by reductions in engine compression ratios beginning with 1971 models. The first Federal standard for nitrogen oxides take effect in FY 1973. With these standards in effect, the levels of nitrogen oxides emitted by new vehicles will begin to show a decline. However, not until the last 3 years of the time period will national

TABLE 3-2. EFFECTS OF CONTROLS ON EMISSION LEVELS, ALL VEHICLES

Fiscal Year	Potential Emissions Without Controls in Effect (Thousands of Tons)			Emissions with Controls in Effect (Thousands of Tons)			Controlled Emissions as Percent of Potential Without Controls in Effect		
	HC	CO	NO_x	HC	CO	NO_x 1/	HC	CO	NO_x 2/
1967	20,000	118,000	7,000	20,000	118,000	7,000	100.0	100.0	100.0
1968	20,800	122,000	7,400	19,200	114,000	7,400	92.5	93.5	100.0
1969	21,700	127,000	7,700	18,500	111,000	7,800	85.5	87.5	101.5
1970	22,400	132,000	7,900	17,300	105,000	7,900	77.0	79.5	100.0
1971	23,300	138,000	8,200	16,000	100,000	8,000	69.5	72.5	97.5
1972	24,000	142,000	8,500	14,600	93,000	7,900	61.0	65.5	93.0
1973	25,000	147,000	8,800	13,200	89,000	7,600	53.0	60.5	86.5
1974	25,600	151,000	9,100	12,000	84,000	7,300	47.0	55.5	80.5
1975	26,500	156,000	9,400	10,500	74,000	6,900	39.5	47.5	73.5
1976	27,400	161,000	9,600	9,000	65,000	6,200	33.0	40.0	64.5
1977	28,000	165,000	9,900	7,700	57,000	5,500	27.5	34.5	55.5

1/ NO_x emissions are increased through 1972 as a side effect of HC and CO controls.

2/ NO_x controls are planned to begin in 1973.

vehicular emissions of nitrogen oxides actually fall below those expected if hydrocarbons and carbon monoxide are not being controlled.

In projections in Table 3-2, consideration was given not only to the age distribution within the vehicle populations each year, but also to the usage of vehicles according to age. Based on total mileage estimates and the number of cars in use, the average mileage driven per year is about 10,800 miles; for HD vehicles, the average is about 12,500 miles (however, the usage of certain classes of HD vehicles deviates greatly from the average). Based on Bureau of Public Roads surveys, the trend is for annual mileage to decrease with the age of the vehicle. Thus, newer vehicles contribute a significantly larger portion of the total mileage and fuel consumption than the older vehicles.

III. STATE-OF-THE-ART OF CONTROL TECHNOLOGY FOR MOBILE SOURCES

A. Conventional Engine Control

1. General

During the past year no dramatic innovations have been observed in control technology for conventional internal combustion engines. Some progress has been made, but in general the concepts and approaches appear the same as previously reported. The ability of industry to meet the 1976 nitrogen oxides standards is still in question. Even proposed unconventional engines may not be capable of meeting this stringent requirement in vehicular service. There is considerable confidence that the 1975 hydrocarbon and carbon monoxide emission standards can be met, although possibly with penalties in driveability and economy.

Problems in driveability and fuel economy have significance beyond questions of mere comfort, convenience, and the user's budget. Driveability problems can include starting difficulties, poor or uncertain acceleration, hesitation and stalling. To the extent that driveability affects safety in traffic these problems influence selection of control techniques. To some degree fuel economy must also be considered in control technique development. Since automobiles comprise a large portion of the Nation's petroleum consumption, unduly large increases in vehicle consumption rates would constitute a drain on national resources. Thus the total effects of various approaches must be considered in achieving control of emissions.

Plans for accommodating unleaded gasoline, which were introduced after last year's report was assembled, have influenced control technology and necessitated engine design changes. Manufacturers are making changes in design and materials for valves and valve seats to prevent damage when using unleaded gasoline. The use of unleaded gasoline will be a necessity for any type of catalytic reactor system. In addition, unleaded gasoline will make exhaust gas recirculation systems more reliable and trouble free. Unleaded gasoline will also reduce the expense of maintaining exhaust systems since corrosion problems will not be as severe. Some engine components give longer life and require less maintenance with unleaded gasoline.

2. Light-Duty Vehicles

The chief developments in control technology for 1971 models appear to lie in the areas of new techniques for regulating carburetion, choking, and engine ignition characteristics. For further progress in this area manufacturers will employ new electronics technology in ignition systems and control of carburetion or fuel injection processes.

Manufacturers feel that this is necessary for them to reduce the maintenance requirements for automobiles in order to meet the Government's requirement for a 50,000 mile warranty of emission control performance. One manufacturer has stated that his goal is a "sealed hood" vehicle which would require no service or maintenance of the engine or associated components for at least 50,000 miles. This would require special lubricants and cooling fluids as well as stable, long-life ignition and fuel systems. This goal has not been met yet, but seems possible in light of current technology.

Table 3-3 summarizes the typical control techniques and engine changes expected as a result of emission control requirements for Fiscal years 1967-77. The technology is well established and manufacturers are committed to certain approaches through 1974. However, in order to meet the stringent 1975 and 1976 standards, certain technical problems must be resolved. Three alternative possibilities for meeting these standards are shown in Table 3-3.

TABLE 3-3. CONTROL TECHNIQUES AND ESTIMATED CONTROL COSTS FOR AUTOS AND LIGHT-DUTY TRUCKS, 1967-77

Model Year		Autos and Light-Duty Trucks Typical Changes or Controls Added	Additional Cost[1] Per New Vehicle (Dollars)	Total Cost[1] Per Vehicle (Cumulative) (Dollars)	Emissions Per Vehicle as Percent of 1967 Vehicle Level		
					HC	CO	NO_x
1967		None	0.00	0.00	100	100	100
1968-1969		Closed PCV system, carburetor changes, ignition timing changes, inlet air temperature control	5.40	5.40	53	45	111
1970		Additional carburetor changes, idle control solenoid, ignition timing changes	7.40	12.80	40	37	85
1971		Evaporative emission control, improved idle control solenoid with overheat protection (including transmission spark control), low compression ratios, additional carburetor changes	19.70[2]	32.50[2]	25	32	85
1972		Valve and valve seat changes for unleaded gasoline	2.00	34.50	20	28	69
1973-1974		Exhaust gas recirculation for NO_x control, speed controlled spark timing	48.00	82.50	20	28	42
1975	Alternative 1	Catalytic oxidation of HC and CO (includes long-life exhaust system), unitized ignition systems for 50,000 mile service-free performance, air injection for catalytic unit	163.50	246.00	12	16	42
1976-1977		Dual catalyst units for HC, CO, and NO_x; or tandem NO_x and CO-HC catalytic units; modified manifold reactors to reduce catalyst load	105.00[2]	351.00[2]	3	3	6
		Cumulative 1974		82.00			
1975	Alternative 2	Extremely lean fuel mixtures (unitized electronic ignition with electronic control of spark timing), electromechanical fuel injection, special valves and intake design	160.00	249.00	12	16	42
1976-1977		Low temperature NO_x decomposition catalyst unit	85.00[2]	334.00[2]	3	3	6
		Cumulative 1974		82.00			
1975	Alternative 3	Catalytic oxidation of exhaust HC and CO, air injection to assist catalytic unit	133.00	215.00	12	16	42
1976-1977		Exhaust gas recirculation increased to maximum for NO_x control. Modulation of recirculation	14.00[2]	229.00[2]	3	3	6

[1] **No Federal Excise Tax included**

[2] Above the costs of controls or simpler system replaced

Alternative 1 requires progress in the development of both an oxidizing catalytic reactor and a reactor for decomposing nitrogen oxides.

Alternative 2 requires research and development work in the use of extremely lean fuel mixtures. The literature reports progress in this area during the last year and offers hope that this approach is not yet exhausted. Extremely lean operating engines would probably use some type of fuel injection system along with improved ignition systems. This second alternative requires progress in development of a satisfactory nitrogen oxide decomposing catalyst which can work with a lean operating engine. It will be necessary to have a catalyst system such that water as well as nitrogen oxides, and ammonia will be produced in the exit gases. If carbon dioxide is reduced, carbon monoxide will be produced in the exit gases or carbon may be formed in the reactor, causing it to eventually malfunction.

Alternative 3 is based on expected developments in oxidizing catalyst reactors and the extension of known principles in exhaust gas recirculation for reduction of nitrogen oxides. Thus, Alternative 3 is the most achievable of the three alternatives considering current technical knowledge. However, it seems unlikely that Alternative 3 can meet the 1976 nitrogen oxides standard even with an elaborate exhaust gas recirculation system. It is likely that a level of 0.8 to 1.0 grams per mile of nitrogen oxides is the minimum level that can be reached with this appraoch. This is approximately twice the level permitted by the 1976 nitrogen oxides standard using proposed test cycles. With the exhaust gas recirculation, a catalytic oxidizing unit would be necessary to achieve the 1975 standards for hydrocarbons and carbon monoxide.

The projected controls shown in Table 3-3 may not be applied by all manufacturers, especially on exactly the same time schedule. There are differences of opinion among the manufacturers on the suitability of controls for the 1975-77 period. However, the techniques tabulated here can be considered typical prospects. Current consensus among domestic manufacturers appears to lean toward Alternative 1 or some variant. Foreign manufacturers seem to show greater expectations for Alternative 2 than do U.S. manufacturers at present; but this may change. In any case, as the most suitable control techniques develop, competitive pressures will tend to make the technology and costs fairly uniform among manufacturers.

3. Heavy-Duty Vehicles (See footnote, page 3-1)

a. Gasoline Engine

Although the assumed emission standards through FY 1977 for heavy-duty gasoline-powered vehicles do not appear as stringent as those for automobiles, considerable effort will be required to achieve compliance on the 1975-77 models. The fact that heavy-duty vehicles operate at nearly full power much of the time increases the problems of emission control. Most U.S. automobiles have considerable power reserve which is seldom used. As a result, small losses in performance may be of little concern. In a heavy-duty vehicle, a small loss in performance may make an engine inadequate for previous applications. This problem could be accentuated by proposed DOT standards for horsepower-to-weight ratios or acceleration capabilities for trucks. Thus operators of heavy-duty vehicles may be forced to move up in an engine line through use of supercharging or larger displacement engines.

Assumed emission standards for heavy-duty gasoline vehicles through FY 1977 are given in the Appendix I. Table 3-4 lists the anticipated controls through FY 1977. Exhaust emission standards for heavy-duty gasoline vehicles can be met through 1974 by minor modifications to current design engines. Such modifications include carburetion improvements, operation with leaner fuel mixtures, and changes in the timing of valve and ignition operation. Some loss in maximum power output may result.

Evaporative emission standards, which are assumed to become effective in 1973, can be met with relative ease. The control system will be very similar to that for automobiles with differences due to

TABLE 3-4. CONTROL TECHNIQUES AND ESTIMATED CONTROL COSTS FOR HEAVY-DUTY VEHICLES, 1967-77[1/]

Model Year	Changes or Controls Added	Additional Cost [2/] Per New Vehicle (Dollars)	Total Cost [2/] Per Vehicle (Cumulative) (Dollars)	Emissions Per Vehicle as Percent of 1967 Vehicle Level		
				HC	CO	NO_x
	Gasoline Trucks and Buses					
1967-69	None	0	0	100	100	100
1970-72	Lean operating carburetion, ignition timing changes	9	9	67	62	100
1973-74	Evaporative emission controls	32	41	32	33	100
1975-77	Exhaust gas recirculation for NO_x, plus air injection for HC, CO, 15-25% increased displacement	201	242	13	23	35
	Diesel Trucks and Buses					
1967-69	None	0	0	100	100	100
1970-74	Improved fuel injectors and careful operation to prevent excess smoke	0	0	100	100	100
1975-77	Extensive derating of operational horsepower range. Larger engines required for some applications compared to previous engines. Injection system design modifications.	1000	1000	48	100	48

[1/] See footnote, page 3-1.

[2/] No Federal Excise Tax included.

fuel system layout and multiple tanks on trucks.

Assumed exhaust standards for 1975-77 are expected to combine hydrocarbons and nitrogen oxides as a composite total limit. The assumed standard is expressed in terms of emission weight per unit of engine work (grams per horsepower hour). This expression takes into account the fact that heavy-duty vehicles make greater utilization of engine work potential than do automobiles and that trucks are powered according to load needs rather than subjective motivations. With exhaust gas recirculation, air injection in exhaust manifolds will be needed to hold down hydrocarbon and carbon monoxide emissions. The use of exhaust gas recirculation for 1975-77 models will cause a loss in performance and fuel economy.

b. Diesel Engine

Diesel engines operate with an excess of air in the combustion cylinders. This accounts largely for diesel engines' lower emissions of hydrocarbons and carbon monoxide, compared with gasoline engines. The air-fuel ratio is varied by the driver rather than being controlled by carburetor design, as in a gasoline engine.

Smoke from diesel engines is a function of the engine loading, speed, the air-fuel ratio, combustion chamber, and fuel injector design. Since some of these factors are the control of the diesel operator, many diesel engines now on the road may be able to meet smoke standards through 1976 if properly maintained and operated. Design changes, such as improved fuel injectors, are currently being incorporated into diesel engines to further improve the performance in terms of smoke and odor emissions. Engine manufacturers are making available smoke reduction kits (with improved fuel injectors) as retrofits which may be required by State regulation.

Possible standards for the 1975-77 period, shown in the Appendix I, will require additional efforts in diesel control. The possible standards in the Appendix are included for completeness, but, at this writing, are illustrative only. As with heavy-duty gasoline vehicles, the assumed 1975 standard for diesels contains a limit of the sum of the hydrocarbon and nitrogen oxides in terms of mass per work done. Opinions vary among diesel manufacturers on the difficulty of meeting the 1974 standards, tending to reflect the experience with the manufacturer's own engine line.

Some diesel engine designs can be modified to achieve 1975 standards (in the manufacturer's opinion). Meeting the standards with these engines would involve derating or operating engines below their full potential output (in the absence of control requirements). To maintain a given power level in specific application, it will be necessary to go to a larger engine (25-30% greater displacement) or to use superchargers (with engines engineered for low emissions). Simply adding superchargers or using a bigger engine does not guarantee lower emissions; other factors must be controlled also. New "prechamber" diesel engines now under development appear capable of meeting the 1975 hydrocarbon,nitrogen oxides standard. However, these engines are presently more smoky and use more fuel than comparable direct injection types. The "prechamber" engines are expected to be more expensive to manufacture than comparable displacement engines using direct injection.

Emissions of carbon monoxide are not considered a serious problem with diesels. Little difficulty is anticipated in meeting standards through FY 1977.

Diesel engines are finding steadily increasing application are are virtually supplanting gasoline power in long-haul vehicles over 20,000 pounds GVW. There has been a trend to larger diesel engines in these vehicles, with ratings over 200 horsepower becoming common. On the other hand, a trend is also developing for application of diesels in "medium" size trucks. The result of both trends will be more diesels on the road unless control costs shift the trends.

4. Unleaded Gasoline

It appears that sufficient unleaded gasoline of 91 to 93 research octane can be made available for automobiles equipped with catalytic reactors for 1975 and beyond. Automobile manufacturers have already lowered compression ratios to permit nominal acceptance of 91 octane fuel, but not all 1971 models operated satisfactorily at this octane level. As a result of the lower compression ratios, fuel economy, performance, or both must be compromised. Manufacturers have struck different compromises here, with fuel economy being the predominant loss overall. Table 3-7 is illustrative of possible operating cost increases.

B. Unconventional Power Sources

There appear to be two widely polarized opinions concerning the potential for development of unconventional power sources through FY 1977. The minority opinion, holding hope for new engines in use by 1975, is held by several groups of inventors and manufacturers, most of whom are outside the automotive industry. The major automotive manufacturers hold that unconventional power sources can have no significant impact through FY 1977. Major design changes in vehicles require 3 to 5 years of leadtime for prototype testing, production engineering, and tooling. This is the case with well-developed concepts. At present most of the unconventional power sources would require several additional years of preliminary development. Therefore, unconventional power plants will be discussed only for information purposes.

Although hybrid power systems consisting of internal combustion engines with electric driving motors represent a combination of well-developed technologies, the problems of the internal combustion engine still exist in this system. Meeting the 1975-76 Federal standards with any internal combustion engine, hybrid or otherwise, will be difficult. Considerable work is required for developing the controls and auxiliary equipment of such a hybrid vehicle. Considering the time required for prototype testing, tooling development, and production setup, it would probably be in the early eighties before hybrid systems could be brought into significant service. This view is reflected in the deemphasis of hybrids in Federal R&D programs.

Gas turbine engines are probably the most well developed and potentially imminent of the alternative power sources. (Indeed, demonstration vehicles powered by turbines have been prepared in previous years by various segments of the auto industry). However, problems still exist with the gas turbines, the chief ones being high manufacturing costs and poor fuel economy at partial load. In addition, it has not been proven that turbines can meet 1976 nitrogen oxides standards. If the reciprocating internal combustion engine is able to achieve the required 1975-76 emission levels, it is unlikely that the additional control costs will be great enough to offset the higher prices of gas turbines for automobiles.

It is likely that gas turbines may find their first application in heavy-duty vehicles where the long life and low maintenance requirements of the turbines will make them more competitive with reciprocating engines. Commercial truck users are conservative in their approach to new equipment. A thorough demonstration of reliability and operating and maintenance economies is needed before wide acceptance is achieved. Engine manufacturers are currently planning to expand the use of turbines in stationary, marine, and off-road applications to build confidence for truck use. It is doubtful that turbine trucks will present a significant national impact through FY 1977.

One manufacturer in particular is investing heavily in development of a small steam turbine engine which he feels could be brought into mass production before FY 1975. However, engineering refinements are needed to make the power plant usable by the general public. This company is following the approach of building a direct interchange unit for use in vehicles basically designed for conventional reciprocating engines. Such an approach is the only one which would offer any hope for radically new engine designs to be brought into production through FY 1977. Major redesign and new concepts in structural components require a leadtime of as much as 5 to 7 years. Although there is some possibility that the steam turbine engine may be brought into production by 1975 or 1976, it does not appear that a major impact would be felt in the automotive industry by FY 1977.

Another area of new engine design involves the Wankel rotating internal combustion engine. The basic design of this engine has been available for a number of years, but the engine has not found significant production application due to problems with its internal seals. Progress is apparently being made in overcoming these problems, however. A Japanese manufacturer has released a production vehicle in the United States with a Wankel engine. For the past several years a European manufacturer has been producing a limited number of Wankel powered cars. Another highly respected European manufacturer is nearing production with Wankel engines for its luxury-priced sports cars; this manufacturer reportedly feels the seal life problems have been solved. Major American manufacturers have been investing millions of dollars in licenses for the right to develop and sell Wankel engines. This is an indication of the seriousness with which the engine is being examined in the auto industry.

It may be possible to produce the Wankel engine at a somewhat lower cost due to its mechanical simplicity, compared to a reciprocating engine. Also, the Wankel engine is much smaller for a given horsepower than the conventional reciprocating engine. This would provide more vehicle room for new safety and emission control features which will be required on automobiles.

The Wankel engine is not inherently a low emission engine. In general, its nitrogen oxides emissions are less than that for a reciprocating engine, but its hydrocarbon and carbon monoxide emissions are considerably higher. The automotive industry, however, is approaching the Wankel engine with a higher degree of confidence (than other new concepts) because of its similarities to other internal combustion engines and the fact that much of the same emission control technology appears applicable. At the present, the outcome of the development work on the Wankel engine through FY 1977 cannot be predicted.

C. New Vehicle Testing and Factory Surveillance

The purpose of motor vehicle assembly line testing is to insure that motor vehicles as manufactured meet emission standards. Section 206 of the Clean Air Act Amendments of 1970 provides for the testing of new vehicles or engines being manufactured, to determine whether they conform with the regulations prescribed under Section 202 of the Act.

Assembly line testing is actually a program of quality control and assurance with two essential parts: the control and assurance program carried out by the manufacturers and the surveillance function carried out by EPA. Federal requirement of assembly line testing may begin with the 1973 model year. Requirement of some form of assembly line testing will continue through 1977 and beyond.

It is assumed that automobile manufacturers, both foreign and domestic, will conduct their own quality control and assurance work to insure that they are in compliance with emission standards. EPA's staff will approve the test methods and procedures, set standards, and monitor the assembly lines by independently selected samples and tests, in addition to auditing test data from the manufacturer.

IV. COSTS OF COMPLIANCE WITH THE 1970 CLEAN AIR ACT AMENDMENTS

A. Types and Sources of Costs

Costs for mobile source compliance with the 1970 Clean Air Act Amendments are of three broad types. First is the increase in prices of new vehicles due to emission controls. Second is the cost of compliance assurance for new vehicles. (This includes factory testing and inspection and regulatory agency monitoring of factory testing.) Both types may be reflected in increased purchase prices for consumers. A third category is increased costs for maintaining and operating vehicles.

Several difficulties are encountered in determining price increases due to emission regulation. One source of difficulty is the differing pricing policies and cost accounting procedures among automobile manufacturers. Variations may occur for example in the allocation of overhead, development costs, and profits to control equipment. The final company decisions in these areas will be dictated by competitive pressures, the company's profit levels and financial position, and Government requests for cost information on a uniform comparable basis.

Costs for controls cannot *a priori* be equated to prices for automobiles to consumers, even if costs are passed on to the consumer. The response of prices is determined by price elasticity of consumer demand for the basic vehicle *and* optional features. The basic utility of a low-priced, 5-passenger sedan is the same as that of a 5-passenger luxury car with every novelty and convenience feature. Thus consumers may choose fewer optional features in automobiles to offset the cost of emission controls, thereby holding their vehicle purchase price nearly constant. This would cause the impact to occur as shifts within the product mix of industry. Alternatively, consumers may extend the useful life of vehicles (i.e., buy fewer) or buy smaller vehicles. Although estimates of demand elasticity may be made, only experience will determine the actual response of consumer prices.

Research and development (R&D) for emissions control in the auto industry is another source of costs. Industry reports to EPA claim large R&D expenditures for emission control. The reported expenditures cannot now be properly evaluated since the methods of accounting and reporting the figures are not fully explained or uniform from company to company. R&D costs can reasonably be expected to rise over the next few years in response to the major 1975 and 1976 deadlines. As mentioned in the preceding paragraph, manufacturers' policies in recovering these costs cannot be predicted at present. In the absence of some external equalization factors, the R&D burden will obviously lie unevenly on manufacturers according to size and profitability.

Another source of costs for new vehicles is the quality assurance aspect of emission standards. These costs include testing and certification of engines and vehicles, inspection and testing of vehicles under production, and Government efforts in factory surveillance, enforcement and monitoring. Certification represents an additional development cost for vehicles. Testing is an additional cost per unit of production. Government enforcement costs are transferred to the public through taxes.

Increases in the continuing expenses of operating and maintaining vehicles are the remaining major compliance cost area. Operating cost increases are due to increased fuel consumption rates and increased prices for fuel. Maintenance cost increases are due to service required by control equipment or to otherwise keep a vehicle at the emission levels permitted by age and design.

Section 207(b) of the Clean Air Act Amendments of 1970 requires that manufacturers warrant the emission performance of vehicles for their "useful life". (A proposed definition of "useful life" was given in the Federal Register, May 11, 1971.) This and related provisions of the Act are being variously interpreted by industry. Regardless of the final mechanism for providing warranty service, it is likely that the purchaser will pay for maintenance and service either at the time of purchase or during the warranty period as mandated by warranty stipulations. Of course, maintenance expenses will continue beyond the warranty period when the Federal cognizance stops (under the current Act provisions). However, in some cases responsibility for enforced maintenance will devolve to the State level.

EPA has recently completed a study of the feasibility of various time schedules for reducing the lead content of gasoline. Several schedules considered reasonable were examined. Consumer prices did not show a great sensitivity to choices among the most likely schedules. The price for unleaded 93 octane gasoline was estimated to range from 1.1 to 3.5 cents per gallon higher than leaded 94 octane regular gasoline over the 1972-80 period. However, approximately 40 percent of the gasoline now sold is premium grade. The need for premium will steadily decline. The basis of cost comparison should be the national average price per gallon (combined premium and regular). On this basis it was indicated that the national average price per gallon would increase slightly less than 2 cents.

Certain benefits (other than emissions reduction) or negative costs can be expected as a result of control measures for gasoline engines. Exhaust systems, spark plugs, and certain other components will have longer lives with the use of unleaded gasoline. Engine oil change intervals can also be extended. The use of electronic (breakerless) ignition and fuel control systems will reduce the frequency of tuneups and will improve engine reliability. A final benefit, difficult to evaluate in dollars, is the stimulus to improve overall manufacturing quality control and to innovate in design and production methods in the automotive industry.

B. Unit Costs of Controls on New Vehicles

Estimated unit control costs (per vehicle) are given along with anticipated controls in Table 3-3 for light-duty vehicles and in Table 3-4 for heavy-duty vehicles. The tables give the incremental costs for controls added through FY 1977 and the cumulative or total cost attributable to control features for each model year. Costs are at retail level and in 1970 dollars. As pointed out in the previous discussion of control technology, the 1976-77 costs are least well defined for light-duty vehicles. For the heavy-duty vehicles, the 1975-77 costs are least well defined, especially for diesels. None of the costs consider combined effects of emission controls and possible new safety requirements which may increase vehicle weights and cause other costs.

Control cost estimates are based on interviews with industry representatives, published prices where available, and engineering estimates of specific features. Estimates for 1968-71 vehicles have been revised on the basis of new information available.

Cost information available directly from manufacturers is presently very limited. In addition, variations in pricing and cost accounting, as previously mentioned, make cost and price data difficult to assess. The fact that industry list prices do not reflect actual selling prices is another complication. Cost data given here are based on estimates of typical sales markups rather than list prices.

Because actual response of prices has not been determined, costs for value of capital and interest charges on investment are not included in the cost reported here. It should be noted that truck purchasers have less ability to maintain prices by rejecting options than do automobile purchasers. For this reason interest values should be considered in a detailed cost analysis when better data are available.

Tables 3-5[2] and 3-6 give estimated unit cost increases for operation and maintenance of light- and heavy-duty vehicles respectively. The increases in operating costs are due to increased fuel consumption. For light-duty vehicles, annual fuel consumption is based on a reference of 760 gallons per vehicle. The baseline for fuel consumption comparisons is Model Year 1967. Consumption increases are estimated to be 6 percent beginning Model Year 1971, an additional 2 percent beginning Model Year 1973, and an additional 7 percent beginning Model Year 1975.

For heavy-duty gasoline vehicles, increases are based on annual averages of 1,380 gallons of fuel with a 15 percent increase in consumption beginning Model Year 1975. Price changes for gasoline are reflected in later tables and not here. For heavy duty diesel vehicles, fuel cost increases are based on an annual average of 10,660 gallons of fuel with an 8 percent increase in consumption beginning Model Year 1975.

In evaluating operating costs for heavy-duty vehicles, it should be noted that the averages include two greatly different groups of vehicle users. The averages are loaded at the low end by a large fraction of trucks used only in urban and short haul applications. These vehicles have low annual mileages. The other group (usually larger and heavier) of heavy-duty vehicles comprises the interurban, long haul services. Although these vehicles are a small fraction numerically, they contribute large annual mileages per vehicle, with 100,000 to 200,000 miles not uncommon.

Annualized investment costs, which may be of greater concern to corporate truck owners than to private automobile owners, are shown in Table 3-6. The amortization schedule is somewhat arbitrary since the life of many

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[2] Alternate 1, Table 3-3, for 1975-76 model light-duty vehicles, is assumed in all calculations and estimates presented.

TABLE 3-5. ANNUALIZED UNIT COST INCREASES FOR LIGHT-DUTY VEHICLES
(Dollars)

Cost Type \ Model Year	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977
Increased Fuel Use				15.90	15.90	21.50	21.50	40.60	40.60	40.60
Maintenance	6.10	6.10	6.10	12.70	12.70	15.50	15.50	50.10[1]	60.40[1]	60.40[1]
Maintenance Offsets								-36.30[2]	-36.30[2]	-36.30[2]
Total Annual Operating and Maintenance	6.10	6.10	6.10	28.60	28.60	37.00	37.00	54.40	64.70	64.70

[1] Based on average of Alternative 1 for 1975-77 shown in Table 3-3.

[2] Offsets for reduced requirements for present type tune ups and exhaust system maintenance.

TABLE 3-6. ANNUALIZED UNIT COST INCREASES FOR HEAVY-DUTY TRUCKS[1]
(Dollars)

Cost Type \ Model Year	1968-69	1970-72	1973	1974	1975	1976	1977
Gasoline Engines							
Increased Fuel Use[2]	None				68.40	68.40	68.40
Maintenance	None		9.90	9.90	31.70	31.70	31.70
Total Operating and Maintenance Penalties	None		9.90	9.90	100.10	100.10	100.10
Annualized Control Investment Costs [3]	None	1.80	8.20	8.20	48.40	48.40	48.40
Total Annualized Cost Increase	None	1.80	18.10	18.10	148.50	148.50	148.50
Diesel Engines							
Increased Fuel Use [4]	None		None	None	222.00	222.00	222.00
Annualized Control Investment Costs [3]	None		None	None	200.00	200.00	200.00
Total Annualized Cost Increase	None		None	None	422.00	422.00	422.00

[1] **See footnote, page 3-1.**

[2] Based on average of 1380 gal. of fuel per year as baseline, fuel at 33¢/gal.

[3] Based on 5-yr. engine life, annualized straight line basis, no Federal Excise Tax included.

[4] Based on average of 10,660 gal. of fuel per year as baseline, fuel at 26¢/gal.

heavy-duty vehicles extends through several engine replacements. Replacement engines may also carry some cost changes as a result of emission controls, but data are not sufficient for evaluation. Interest values or value of capital have not been included in heavy-duty vehicle annual costs because of these amortization complications.

Tables 3-5 and 3-6 also show annual figures for maintenance cost increases. Maintenance cost increases are based on 1970-dollar value estimates of labor and parts requirements. In some cases maintenance cost offsets are expected (as previously explained). No inflation factors are included.

To provide perspective on the annualized cost increases shown in Tables 3-5 and 3-6, comparisons may be made with present costs of vehicle purchase and operation. An average 1970 model, U.S.-made automobile retailed for about $3,470, including Federal tax, accessories and other costs except State taxes and fees. For an automobile of this price, the Bureau of Public Roads (BPR) has estimated an individual owner's annual costs at $2,060 for the first year and $1,470 for the second, decreasing to $1,140 for the ninth year of vehicle life. The BPR data includes depreciation, maintenance, operating costs, garaging costs, taxes, fees, insurance, and all other costs directly attributable to automobile ownership and use, except financing costs or value of capital.

In 1970 heavy-duty diesel truck tractors in the 18- to 38-ton rating range, ready for road hauling, typically were priced at $19,000 to $24,000. A representative 20-ton diesel dump truck (with dump body) cost $22,000 in the same year. Gasoline engine trucks typically cost $4,000 to $5,000 less than comparably rated diesel trucks, and weigh about a ton less. (Few new gasoline trucks in the sizes above 13 tons are anticipated in the next few years, however.)

C. National Costs Through 1977

Table 3-7 summarizes national costs by vehicle class through FY 1977. Investment costs are purchase price increases for new vehicles during the indicated year. Annual operating and maintenance costs are the increased costs due to controls for all controlled vehicles in use for the specified year. Gasoline price increases due to unleaded gasoline cover all vehicles and consider the projected change in demand patterns due to controls, as well

TABLE 3-7. NATIONAL COSTS FOR MOBILE SOURCE COMPLIANCE
(Millions of Dollars)

Cost Type (Increases) / Fiscal Year	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	Totals, 1968 Through 1977
Light-Duty Vehicles											
New Investment 1/	40.6	52.9	114.6	267.5	369.5	809.5	954.0	2,528.0	4,061.0	4,463.0	13,660.6
Assembly Line Testing 2/					2.5	34.8	35.4	36.3	36.9	37.8	183.7
Annual Operating and Maintenance	41.5	97.2	154.4	379.3	662.6	1,016.1	1,394.7	1,916.8	2,581.6	3,267.3	11,511.5
L.D. Total	82.1	150.1	269.0	646.8	1,034.6	1,860.4	2,384.1	4,481.1	6,679.5	7,768.1	25,355.8
Heavy-Duty Gasoline Vehicles 3/											
New Investment 1/			4.2	5.4	5.7	22.9	28.6	147.1	185.2	195.0	594.1
Annual Operating and Maintenance						5.3	12.5	72.6	153.4	236.6	480.4
H.D. Gas Total			4.2	5.4	5.7	28.2	41.1	219.7	338.6	431.6	1,074.5
Gasoline Price 4/ Increases due to Lead Removal								10.7	22.3	34.8	67.8
Total all Gasoline Vehicles	82.1	150.1	273.2	652.2	1,040.3	1,888.6	2,425.2	4,711.5	7,040.4	8,234.5	26,498.1
Heavy-Duty Diesel Vehicles 3/											
New Investment 1/								68.0	92.0	101.0	261.0
Annual Operating								15.1	31.5	49.5	96.1
H.D. Diesel Total								83.1	123.5	150.5	357.1
All Vehicles Total	82.1	150.1	273.2	652.2	1,040.3	1,888.6	2,425.2	4,794.6	7,163.9	8,385.0	26,855.2

1/ No Federal Excise Tax included in investment costs.

2/ Assumes inspection program (partially implemented 1972) with 3 percent of production tested beginning 1973, average cost $3.00 per vehicle produced (includes foreign and domestic production for U.S. consumption).

3/ See footnote, page 3-1.

4/ Considers changes in demand patterns and fuel penalties as a result of controls as well as added costs of producing gasoline.

TABLE 3-8. - NATIONAL COSTS OF MOBILE SOURCE CONTROL
AND EMISSION REDUCTIONS FROM 1967 BASELINE 1/

	Reduction from 1967 National Mobile Source Emissions Level (percent)			National Costs 2/ of Controls (Millions of Dollars)	
Year	HC	CO	NO_x	For Year	Cumulative
1967	--	--	--	--	--
1968	4.0	3.5	(5.5) 2/	82.1	82.1
1969	7.5	6.0	(11.0)	150.1	232.2
1970	13.5	11.0	(12.5)	273.2	505.4
1971	20.0	15.0	(14.0)	652.2	1,157.6
1972	27.0	21.5	(12.5)	1,040.3	2,197.9
1973	34.0	25.0	(8.5)	1,888.6	4,086.5
1974	40.0	29.0	(4.0)	2,425.2	6,511.7
1975	47.5	37.5	1.5	4,794.6	11,306.3
1976	55.0	45.0	11.5	7,163.9	18,470.2
1977	61.5	53.0	21.5	8,385.0	26,855.2

1/ See footnote, page 3-1.

2/ No Federal Excise Tax included in costs.

3/ Figures in parentheses are increases.

as the fuel consumption penalties. The changes in national average gasoline prices are not as great as might be expected because the drop in demand for premium gasoline tends to offset both the cost and demand increases for unleaded regular gasoline.

National costs given in Table 3-7 are only those directly resulting from Federal requirements. Costs from State activities and indirect costs due to Federal expenditures are not included. Cost changes for vehicles or fuel due to emissions control in supplier industries are also not included. Possible interrelationships with costs of Federal safety standards are not included.

Table 3-8 shows the reductions in national mobile source emissions compared to 1967 levels and gives the costs of achieving these reductions. This table illustrates that improvements will be achieved compared to 1967 conditions and not just relative to the potential emissions from vehicle population growth through FY 1977.

Detailed discussions of the problems of State inspection programs and assembly line testing are appended at the end of this report. These analyses, originally prepared as separate reports, are reprinted here as Appendixes II and III, respectively.

Chapter 4: Stationary Sources

I. INTRODUCTION

The impact of air pollution controls on 20 categories of stationary sources is discussed in this chapter. The analyses of each category cover the significant combustion and process steps, the emissions by type and quantity, the methods of controlling emissions to comply with standards established under the Clean Air Act Amendments of 1970, the expected costs of controls, and the economic impact of these costs. The assumed standards are those presented in Appendix II of the instruction for preparation of State implementation plans which appeared in the Federal Register on August 14, 1971. If States adopt other emission standards, the actual costs will vary accordingly.

The 20 categories of stationary sources are grouped below under three headings--solid waste disposal (Section II), stationary fuel combustion (Section III), and industrial processes (Section IV). Five types of emissions discussed are particulates, oxides of sulfur, carbon monoxide, hydrocarbons, and oxides of nitrogen. Table 4-1 summarizes the quantities and control costs for the five emission types and the three source groupings. Control costs shown are the total investment requirements through FY 1977 and the annual costs for sources estimated to be operating in FY 1977. Annual costs, including both operating and capitalization expenses, are those forecast under the assumption that the standards established under the Clean Air Act will be fully implemented.

The year 1967 was selected as the data baseline so that costs and changes in emissions would be those occurring after the passage of the Clean Air Act and, therefore, are assumed to be attributable to the economic impact of program implementation. All dollar amounts are expressed in 1970 prices and constant 1970 dollars.

By using 1967 as a data base, emission and cost estimates for FY 1977 for solid waste disposal and for residential, commercial, industrial, and small and intermediate utility boilers were computed using projected growth of the source capacities and fuel-use trends. For all other sources (steam-electric and industrial processes), emissions and cost estimates for FY 1977 were computed using projected growth for source production and capacity, respectively, since it was not possible to determine accurately whether growth would result from

TABLE 4-1. STATIONARY SOURCES -- ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS IN 1967 AND 1977

		Quantity of Emissions[1] (Thousands of Tons per Year)					Control Costs (Millions of Dollars)	
Source	Year	Part	SO_x	CO	HC	NO_x	Investment	Annual
Solid Waste Disposal	1967	1,210	170	4,440	1,670	340[2]		
	FY 77 W/O[3]	1,830	260	6,720	2,530	510		
	FY 77 W[4]	65	260	512	360	510	472	224
Stationary Fuel Combustion	1967	7,710	23,900			7,200[2]		
	FY 77 W/O	7,930	35,000			10,800		
	FY 77 W	3,180	4,020			10,800	5.539	2,476
Industrial Processes	1967	6,620	6,280	12,500	1,190	145		
	FY 77 W/O	7,980	8,030	15,900	1,550	230		
	FY 77 W	1,050	939	279	308	25	4,135	1,213
Total	1967	15,500	30,300	17,000	2,860	7,690[5]		
	FY 77 W/O	17,700	43,300	22,600	4,080	11,500		
	FY 77 W	4,300	5,220	791	668	11,300	10,100	3,900

[1] Emission abbreviations are: particulates (Part), sulfur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x). Blanks in the table indicate the emission levels meet the applicable regulation (Appendix I) or that emissions are negligible or do not exist.

[2] These estimates are included herein but are discussed no further in Chapter 4.

[3] Estimates without implementation of the Clean Air Act, as amended.

[4] Estimates with implementation of the Clean Air Act, as amended.

[5] An additional 2,300,000 tons of NO_x were emitted in 1967 from natural gas production and its transmission. This estimate is projected to be 3,440,000 tons in 1977.

expansion of 1967 plants and installations or from construction of new facilities. For all source categories, it was assumed that new capacities coming into existence after 1967 would (without requirements of the Clean Air Act) be operated on 1967 control levels, so the control costs attributable to the Act would be only those required to go from 1967 control levels to the levels implemented under the Act. The approach described implicitly assumes that equipment costs and operating expenses remain unchanged, expressed in 1970 prices. Within the limits of these assumptions, this approach provides a reasonable approximation of the increased emissions and costs associated with real economic growth from FY 1967 through FY 1977.

Some of the tables in this chapter include a column headed "Associated Emission Control Level." The percentages shown in this column reflect estimates of the extent to which potential emissions are controlled. For example, in Table 4-6, pertaining to fuel combustion sources, the 4,310,000 tons of particulate emissions from small and intermediate boilers in 1967 are estimated to be about 56 percent of potential emissions of particulate matter. That is, if there had been no control, the emission level would have been 7,750,000 tons. Thus, the level of associated emission control is 44 percent (100 percent minus 56 percent).

The discussions of solid waste disposal and stationary fuel combustion (Sections II and III) emphasize the amounts of emissions and the controls necessary for their abatement. The discussion of industrial processes (Section IV), in addition to emissions and controls, emphasizes the economic impact of control costs on each industry or group of industries studied. Consideration is given to the probable effects on individual firms in each industry, to potential changes in prices, profits, and the structure of the industry, and to market changes. Finally, Section V summarizes the conclusions derived from the economic analyses.

II. SOLID WASTE DISPOSAL

A. Introduction

It was estimated in 1967 that 364 million tons of solid waste were generated in the United States by households, institutions, and commercial and industrial enterprises. The amount generated appears to vary in proportion to population and is generally predicted as a per capita rate. In 1967, total solid waste equalled 10.2 pounds per day per capita for a population of just under 196 million. By 1977, the rate is expected to increase to 13.7 pounds per day per capita. If the population is 222 million, the total will reach 554 million tons.

In 1967, it was estimated that for each 10.2 pounds of waste generated, 5.5 pounds were collected and disposed of by municipal systems and 4.7 pounds by nonmunicipal systems. The latter included industrial incinerators and dumps, building incinerators, and open burning or dumping by households and farms. Municipal systems took the form of incineration (10 percent), open burning (44 percent), and others (46 percent), including sanitary landfill, ocean dumping, and composting. Air pollution emissions resulted from open burning and from incinerators.

B. Engineering Basis of the Analysis

1. Methodology

Air pollution control costs for solid waste were obtained by:

(a) Determining the quantity and method of disposal of collected refuse.

The total collected refuse generated in any State was computed on the basis of 5.5 pounds per capita per day. The amount of refuse incinerated was obtained from incinerator listings obtained from previous studies. All incinerators were assumed to be operating at their stated capacity, and the balance of the refuse which was not incinerated was assumed to be disposed of by other methods: landfill, burning dumps, ocean dumping, composting, etc. When no detailed information on the method of disposal existed, it was assumed that 33 percent of this remaining amount was open burned.

(b) Determining the quantity and method of disposal of uncollected refuse.

Uncollected refuse was estimated using a rate of 4.7 pounds per capita per day. This refuse was assumed to be presently disposed of by 50 percent landfill, 25 percent open burning, and 25 percent domestic and commercial incineration.

(c) Determining incinerator control costs.

All existing municipal incinerators must be upgraded to some extent to comply with regulations. The cost for this upgrading is presented in Table 4-2.

(d) Determining open burning control costs for collected refuse.

All present open burning must be discontinued. It was assumed that 25 percent of this amount would go to new incinerators at a cost of $5,600 per daily ton for furnaces in the 300-ton-per-day or larger size, and $7,500 per daily ton for furnaces smaller than 300 tons per day. The annualized cost of operating an incinerator

TABLE 4-2. COST OF UPGRADING MUNICIPAL INCINERATORS

Year of Construction	Cost of Upgrading ($ per daily ton of capacity)	
	Investment	Annual
Before 1961	500	360
1961-1964	400	330
1965-1967	200	310

was based on $6 per daily ton and 300 days per year. The remaining 75 percent of open burning would go to sanitary landfills at an additional cost of $0.30 per ton. This is the only cost above that required to operate a burning dump.

No initial investment costs were included since land and personnel for the burning dump were already on hand. In metropolitan areas where there are no municipal incinerators, all open burning would be converted to sanitary landfill; that is, no new incinerators will be built in these areas.

(e) Determining control costs for uncollected refuse.

Uncollected refuse control costs were based on all current open burning (25 percent of all solid waste) going to sanitary landfill at a cost of $0.40 per ton, and existing incineration (also 25 percent of the total) requiring upgrading at an investment cost of $1000 per daily ton of capacity with an annualized cost of $259 per daily ton. Presently, twenty percent of existing small incinerators were assumed to meet the New York State regulation, and 20 percent were assumed to convert to landfill at no additional cost.

(f) Determining additional costs incurred by 1976.

These costs were based on the 1967 disposal practices, but were varied to accommodate population changes as well as a 3 percent yearly increase in the amount of solid waste generated per capita. These increases were then treated in the same manner as the 1967 values to arrive at a control cost.

(g) Assuming that all California incinerators were controlled through local efforts and any costs incurred were due to Federal action.

The major single factor is the cost for new incinerators required to control 25 percent of the existing open burning. The high initial costs and the high yearly costs accounted for about

50 percent of the total annual costs for this metropolitan area.

The installation of electrostatic precipitators (ESP's) in place of scrubbers on existing municipal incinerators was also investigated. Annualized costs for ESP's are about 50 percent of scrubber costs. However, since no ESP's are currently used for controlling particulate emissions from incinerators, they were not considered in this analysis. Assuming some of the larger incinerators were to go to ESP's as a means of control, typical annualized cost would be reduced by about 10 percent.

Cost estimates for disposing of junked automobiles in controlled incinerators were based on an assumption that 50 percent of these automobiles were now being open burned. Based on data presented later in this section, the costs of controlling particulates from auto body incinerators would add only about 1 to 3 percent to the investment cost and even less to the annualized cost. Therefore, separate estimates of the cost of controlling junked auto disposals were not made because the percentage contribution of these costs was less than the expected error of the major cost estimates.

2. Control Costs

The following air pollution control costs were utilized in estimating solid waste disposal expenditures.

a. Municipal Incinerator Control Costs

Table 4-3 presents the cost of controlling municipal incinerators with wet scrubbers.

Since installed costs did not vary by more than about 10 percent, an average cost of $500 per daily ton was used. For incinerators built between 1961 and 1964, 80 percent of the control costs were used. For units built after 1965, a control cost of $200 per daily ton was arbitrarily used since these units were assumed to have some type of acceptable control device already in place.

Annualized costs were based on a 13.3 percent capital charge and on the following operating cost equation:

$$C = S\,[0.745HK\,(Z + \frac{Qh}{1980}) + WHL + M] = 0.3985$$

where: S = acfm;
H = 7200 hours/year;
K = \$0.01/kwh
Q = 0.01 gals/acfm;
Z = 0.006 hp/acfm;
W = 0.005 gals/hr acfm;
M = \$0.03/acfm;
h = 30 feet;
L = $\$0.05 \times 10^{-3}$/gal.

Operating costs for a wide range of incinerator sizes were calculated and an average cost was based on dollars per ton used for cost estimating purposes.

TABLE 4-3. MUNICIPAL INCINERATOR CONTROL COSTS

Size (tons/day)	Flue Gas Volume (1000 acfm)1/	Collection Eff. (percent)	Installed Cost		Annualized Cost	
			($1000 total)	($/daily ton)	($1000)	($/daily ton)
50	40	85	28	560	20	400
100	80	85	52	520	39	390
200	160	85	100	500	77	380
300	240	85	150	500	115	380
500	350	90	250	500	172	340
600	420	90	300	500	207	340
700	420	95	350	500	213	300
1000	600	95	480	480	302	300

1/ For sizes 50 - 300 tons per day, use 800 acfm/ton.
For sizes 500 - 600 tons per day, use 700 acfm/ton.
For sizes 700 tons per day and larger, use 600 acfm/ton.

b. Control Costs for Smaller Sized Incinerators

A one-ton-per-day model size unit operating for 5 hours per day and 360 days per year (1800 hours per year) was used as a base for calculating control cost. Installed cost of a scrubber for this size unit (400 pounds per hour capacity) designed to meet the New York

State regulation is about \$1000.[1] Particulate control efficiencies on the order of 60 to 90 percent are required.

Annualized control costs were calculated as follows:

$$C = S[0.7457HKZ + \frac{Qh}{1980} + WHL + M] = 920\ (0.119)$$

$$= \$109/\text{year/daily ton}$$

where:

S = 920 acfm[2];
H = 1800 hours/year;
K = \$0.01/kwh;
Z = 0.006 hp/acfm;
Q = 0.01 gals/acfm;
h = 30 feet;
W = 0.005 gal/hr acfm;
L = \$0.05 x 10^{-3}/gal;
M = \$0.03/acfm.

Capital charges at 15%, (.15 x \$1000) = \$150/year/daily ton
TOTAL Annualized Cost = \$259/daily ton

c. Auto Body Disposal Costs

Calculations to determine investment and annual costs of auto body disposal for a metropolitan area are presented below. A controlled incinerator handling 30 cars per day costs about \$25,000.

(1) Investment Cost:

$$\text{Investment Cost/Car} = \frac{\$25{,}000}{30 \text{ cars/day} \times 300 \text{ days/year}} = \$2.8/\text{car/year}.$$

$$\text{Metropolitan Area Investment Cost} = \frac{\text{metropolitan area population}}{1000} \times \frac{27 \text{ cars}}{1 \text{ year}}$$

$$\times\ 0.50^{3/} \times \$2.8/\text{car/year} = \$39/1000 \text{ population}.$$

(2) Operating Cost, assuming \$4/car:

$$\text{Metropolitan Area Operating Cost} = \frac{\text{metropolitan area population}}{1000} \times \frac{27 \text{ cars}/1000 \text{ population}}{1 \text{ year}}$$

$$\times\ 0.50^{3/} \times \$4/\text{car} = \$56/1000 \text{ population/year}.$$

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[1] An average value; control costs for small incinerators vary from \$600 to \$1300 per daily ton of refuse burned.

[2] Based on 16,000 ft^3 of flue gas per 10^6 Btu of heat input, and 5000 Btu/lb of refuse.

$$5000\ \frac{\text{Btu}}{\text{lb.}} \times 4000 \text{ lb/hr} \times \frac{1}{60 \text{ min/hr}} \times \frac{16{,}000 \text{ ft}^3}{10^6 \text{ Btu}} = 535 \text{ ft}^3/\text{min at } 70°\text{F},$$

or about 920 acfm at 450°F.

[3] Assuming 50 percent of all scrapped cars are presently being burned.

All uncontrolled emissions were based upon the emission rate shown in Table 4-4.

TABLE 4-4. EMISSION RATES FOR VARIOUS SOLID WASTE DISPOSAL PRACTICES[1]

Process	Particulate	Hydrocarbons[2]	Carbon Monoxide
Open Burning	17	30	85
Municipal Incinerators	17	1.5	1.0
Domestic & Commercial Incinerators	12	7	15
Sanitary Landfill	0	0	0

[1] Pounds per ton of refuse.

[2] As Methane.

C. Emissions and Control Techniques

Open burning and incineration of solid waste result primarily in air pollutant emissions of particulates, hydrocarbons, and carbon monoxide. It is estimated that the 1967 totals in the United States amounted to 1,207,000 tons of particulates, 1,670,000 tons of hydrocarbons, and 4,438,000 tons of carbon monoxide. If the disposal practices existing in 1967 continued unchanged through FY 1977, the projected level would reach 1,829,000 tons, 2,530,000 tons, and 6,720,000 tons, respectively.

For the purpose of estimating control costs and reduction efficiencies, the following control techniques were designated: (1) all of the open burning by existing municipal systems would be discontinued--25 percent would be disposed of in new municipal incinerators and 75 percent in sanitary landfills; (2) all open burning by private disposal agencies would be discontinued; (3) all municipal incinerators and 80 percent of the large commercial incinerators would be equipped with electrostatic precipitators to control particulate emissions; (4) all of the existing small residential and commercial incinerators would either be replaced by reallocation to sanitary landfills (25 percent) or upgraded by addition of electrostatic precipitators, scrubbers, or other control devices.

Implementation of these controls would, it is estimated, reduce particulates to 65,000 tons, hydrocarbons to 360,000 tons, and carbon monoxide to 512,000 tons in FY 1977. These reductions would represent 96.4 percent control of particulates, 85.8 percent control of hydrocarbons, and 92.4 percent control of carbon monoxide.

D. Scope and Limitations of Analysis

There are several sources of emissions, such as open burning of leaves, burning at construction sites, and disposal of wood wastes in wigwam burners, which have not been included in this analysis. The trend among State and local regulatory agencies is to prohibit such practices, resulting in up to 100 percent control. Since there are several alternatives for each type of disposal, it is difficult to project an ultimate disposal pattern and the costs (if any) which are involved.

Costs and emissions considered in this analysis are limited to collected municipal refuse (incinerated and open burned), other open burning dumps, and onsite incinerators.

E. Cost of Control

For the Nation as a whole, the 1967 level of waste generation would require a capital investment of approximately $311 million to implement the control plan, and holding prices at the 1970 level, the growth of solid waste by FY 1977 would increase the capital investment to approximately $472 million. The annual operating cost of these controls would be approximately $147 million in FY 1967 and is estimated to rise to $224 million by FY 1977.

The public share of the costs required to implement these controls by FY 1977 would be $354 million for capital investment and $165 million for annual operating expenses, including interest and depreciation. Private households, institutions and businesses would bear the remaining $118 million for capital investment and $59 million for annual operating expenses.

The significances of these figures may be indicated, in part, by the investments and annual costs required for specific installations and operations. For example, applying controls to a small incinerator, such as one in an apartment building, will require a capital investment of approximately $1,115 per ton of daily capacity, and an annual operating cost of $295 per ton of daily capacity. To provide sanitary landfill as an alternative to incineration or open burning would require an annual operating cost of $0.46 for each ton of waste. Controlling an existing municipal incinerator would require a capital investment of $225 to $600 per ton of daily capacity and an annual cost of $350 to $410 per ton of daily capacity.

F. Economic Impact

If the municipal costs shown are averaged over the entire U.S. population for 1977, an investment of approximately $6.40 per family and annual costs of approximately $3.00 per family are indicated. Such figures are somewhat misleading, however, since actual costs will vary widely from one community to another. Sanitary landfills are generally considerably more economical for smaller communities outside major metropolitan areas, but incinerators will probably prove less costly for large cities. The break-even point between incineration and landfill, relative to municipal population, is determined by the cost of the disposal facilities in combination with such other factors as availability and price of land, distances over which waste must be transported, population density, and the possibility of sharing facilities with other municipalities. The current analyses do not include all these factors.

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III. STATIONARY FUEL COMBUSTION

A. Introduction

Stationary fossil fuel (coal, oil, and gas) combustion sources analyzed in this study are residential, commercial, industrial, and steam-electric power plants.

The opportunities for abatement control are quite apparent in fossil fuel combustion because these sources account for a substantial majority of the most significant pollutants, in terms of their economic damages. The relative magnitude of emissions of fossil fuel combustion is shown in Table 4-1. Carbon monoxide and hydrocarbon pollutants are not emitted in significant quantities when the combustion equipment is operating properly. No reliable basis was available for estimating costs of NO_x pollutant reductions. Table 4-5 indicates the amount of particulate matter and sulfur oxides contributed by each combustion source.

Two standards were selected as the bases of estimating the cost of controlling emissions from fuel combustion sources. The first is the combustion regulation, which limits particulate emissions to 0.10 pound per million Btu input (based on the source test method described in the Appendix I). The second limits sulfur oxide emissions from fuel combustion sources to 1.50 pounds per million Btu input.

In the past it has been assumed that the control of particulate and sulfur oxide emissions from stationary fuel combustion sources could be achieved by switching fuel--that is, by using low sulfur oil in place of other fuels. Further study has indicated that the availability of low sulfur oil and natural gas should satisfy the present and future requirements for small and intermediate boilers. However, for steam-electric power plants, a complete switch from high sulfur coal and oil to low sulfur oil is not feasible because of long-term fuel supply and demand requirements. Accordingly, a mix of alternatives was assumed including dependence to a large degree on the use of stack gas cleaning devices for the control of both sulfur oxides and particulate emissions. Limited fuel switching has been included for the control of smaller boilers only--below 50 megawatt ratings--and located in power plants with a total rated capacity of less than 200 megawatt.

TABLE 4-5. ESTIMATED EMISSION LEVELS FOR STATIONARY FUEL COMBUSTION SOURCES NATIONALLY

[Calendar Year 1967]

Source	Total Number of Boilers	Quantity of Emissions[1/] (Thousands of Tons per Year)		
		Part	SO_x	NO_x
Residential, Commercial, and Industrial Heating Plants	31,300,000	4,310	8,480	3,200
Steam-Electric Power Plants[2/]	2,600	3,400	15,400	4,000
Total		7,710	23,880	7,200

[1/] Emission abbreviations are: particulates (Part), sulfur oxides (SO_x), and nitrogen oxides (NO_x).

[2/] Power plants shown are investor and municipally owned plants of 200 megawatts and larger.

As noted in Table 4-1, the control plan projected to FY 1977 in this study would reduce the potential particulate emissions from 7,930,000 to 3,180,000 tons and sulfur oxide emissions from 34,960,000 to 4,020,000 tons--reductions of 59.9 percent and 88.5 percent, respectively. Total investment for FY 1977 for this control plan would be $5,539 million and annual costs would be $2,476 million. The impact of the control plan on each fuel combustion source is shown in Table 4-6 and discussed in the sections that follow. Section B covers small and intermediate stationary combustion sources. Section C covers the large steam-electric utility sources.

B. Residential, Commercial, Industrial, and Small Utility Boilers

1. Introduction

Residential, commercial, industrial, and small utility boilers are further divided between the residential sector and the others which will be called intermediate boilers. The intermediate boiler sector includes all steam-raising equipment, hot water heaters, and hot air furnaces used for space heating. The capacity ranges from 200,000 Btu per hour to 500,000 pounds per hour of steam (approximately 50 megawatts [electric]).

All sources which could be subject to a fuel switching emission control scheme are discussed. In the residential sector, gas ranges, air conditioners, clothes driers, and other appliances are fuel consumers which are not included because they contribute a very small portion of the emissions and are not amenable to any control scheme. Utility boilers in the 25 to 50 megawatt (electric) size range, which are located at plant sites with a total capacity of 200 megawatts (electric) or more, are included in the steam-electric section since we assume that these boilers will be controlled by flue gas cleaning rather than by fuel switching.

2. 1967 Summary

Table 4-7 shows the 1967 summary of estimated capacity, fuel use, and emissions from the residential sector and from intermediate boilers. The capacity estimate is a result of a survey of sales data and other statistical data on lifespans for the various boiler types. The fuel use and emission estimates were calculated from capacity,

TABLE 4-6. STATIONARY FUEL COMBUSTION SOURCES -- ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS

Source	Year	Quantity of Emissions 1/ (Thousands of Tons per Year)			Associated Emission Control Level 1/ (Percent)			Control Costs (Millions of Dollars)	
		Part	SO_x	NO_x	Part	SO_x	NO_x	Investment	Annual
Small and Intermediate Boilers	1967	4,310	8,480	3,200	45	0	0		
	FY 77 W/O 2/	2,330	7,360	7,100	58.9	0	0		
	FY 77 W 3/	380	1,260	7,100	93.3	83	0	879	1,116
Steam-Electric Power Plants	1967	3,400	15,400	4,300	78	0	0		
	FY 77 W/O	5,600	27,600	7,200	78	0	0		
	FY 77 W	2,800	2,760	7,200	98.5	90	0	4,660	1,360

1/ Emission abbreviations are: particulates (Part), sulfur oxides (SO_x), and nitrogen oxides (NO_x).

2/ Estimates without (W/O) implementation of the Clean Air Act are shown.

3/ Estimates with (W) implementation of the Clean Air Act are shown.

TABLE 4-7. SUMMARY OF ESTIMATED CAPACITY, FUEL USE, AND EMISSIONS, 1967
(RESIDENTIAL AND INTERMEDIATE BOILERS)

Sources	Capacity	Fuel Use				Emissions			
	10^6 pph	Coal 10^6 Tons	Residual Oil 10^6 Bbl	Distillate Oil 10^6 Bbl	Gas 10^{12} cf	SO_x 10^6 tons	NO_x 10^6 tons	Particulates 10^6 Tons	
								Potential	Actual
Residential	2,117	---	---	355	3.15	0.24	0.2	0.09	0.09
Intermediate Boilers	3,290	148	340	120	3.87	8.24	3.2	7.66	4.22

Source: John R. Ehrenfeld et al., Systematic Study of Air Pollution From Intermediate-Size Fossil-Fuel Combustion Equipment. Contract No. CPA 22-69-85. Cambridge, Mass: Walden Research Corp., July 1971.

load factor, boiler efficiency, collector efficiency, emission factors, and fuel-heating value information. The capacity numbers were further broken down by user, fuel, size, firing type, and age.

The residential sector was dropped from the analysis for the following reasons: (1) coal is rapidly declining as a residential fuel [1] due to "natural attrition," and emissions from other residential fuels (distillate oil and gas) fall within the standards; and (2) essentially all new growth in the residential sector is expected to use gas or electricity for heating. Thus no costs were attributed to control of residential heating units.

3. Projections for FY 1977

Table 4-8 shows the estimated capacity in FY 1977 and the estimated fuel use patterns and emissions with and without the effect of the Clean Air Act. The projections are based on past trends, without placing supply limitations on fuels. Capacity was derived from correlations of boiler sales with economic indicators such as GNP, and the fuel-use pattern, with the Clean Air Act, was based on the fuel-switching strategy discussed below.

4. Control Strategy

Fuel switching is the most cost-effective strategy for reducing emissions from intermediate boilers. The best alternate approach appears to be alkaline scrubbing of the flue gas, but this approach is not as effective in reducing emissions, and the capital cost is nearly twice as high as for fuel switching.

The basic approach of fuel switching is to replace coal and high sulfur residual oil with gas, distillate oil, or low sulfur residual oil, depending on the feasibility for each boiler. The costs of the fuel-switching strategy for 565,000 boilers will result in total reductions of sulfur oxides and particulates by 84 percent. The investment cost is $879 million, and the annual cost is $1,116 million, based on 1967 fuel prices and 1967 dollars in capital costs.

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[1] The rapid decline in the use of coal as a residential fuel has been going on for a number of years, and the cause should not be attributed to the Clean Air Act.

TABLE 4-8. SUMMARY OF ESTIMATED PROJECTED CAPACITY FUEL USE AND EMISSIONS, 1977
(RESIDENTIAL AND INTERMEDIATE BOILERS)

Sources	Capacity	Fuel Use				Emissions			
	Steam 10^6 pph	Coal 10^6 Tons	Distillate Oil 10^6 Bbl	Residual Oil 10^6 Bbl	Gas 10^{12}cf	SO_x 10^6 tons	NO_x 10^6 tons	Particulates 10^6 Tons	
								Potential	Actual
Intermediate Boilers W/O the Act	4,530	102	530	220	7.43	7.36	3.2	5.67	2.33
Intermediate Boilers with the Act	4,530	0	714	245	8.80	1.26	3.2	0.92	0.38

Source: John R. Ehrenfeld, et al. Systematic Study of Air Pollution From Intermediate-Size Fossil-Fuel Combustion Equipment. Contract No. CPA 22-69-85. Cambridge, Mass: Walden Research Corp., July 1971.

Several important assumptions were made in determining the feasibility of the fuel-switching strategy. The 1967 price structure for the various fuels was used, and no restrictions on fuel supply were assumed, although at the present time the future supply and price level of fuels are somewhat uncertain. As the supply of "clean fuels" becomes more restricted and the prices rise, the advantage of fuel switching over flue gas cleaning will become less. However, fuel switching still appears to be the most feasible solution for intermediate boilers in the near future. In order for flue gas cleaning to become attractive by FY 1977, fuel prices for oil and gas will have to rise to twice the 1967 levels.

5. Costs

The costs, as stated above, to implement the fuel-switching strategy include capital costs for converting the boilers to burn a different fuel and additional operating costs for burning more expensive fuels. The capital cost includes costs for burner modifications, fuel supply system changes, and necessary fuel storage facilities. The annual cost includes the annualized capital cost based on 15-year straight line depreciation and 8 percent interest, and the additional fuel costs.

C. Steam-Electric Power Plants

1. Introduction

In 1967, there were 940 steam-electric utility stations representing 397 companies, both investor and municipally owned. In that year, these plants produced some 970 billion kilowatt-hours of energy for sale in the United States. In addition, utility companies produced some 220 billion kilowatt-hours by hydroelectric and nuclear generating stations. Trends in electric energy produced by fossil fuels consumption are shown in Table 4-9 for the most recent 5 years for which data are available.

2. Present and Projected Emissions

Recent trends and projected plans for fossil fuel power plants suggest that coal and residual oil consumption should grow at an annual rate of about 6 percent. Thus, the 1967 level of 3.40 million tons of particulates, 15.4 million tons of sulfur dioxide,

TABLE 4-9. ELECTRICAL ENERGY PRODUCTION AND FUEL CONSUMPTION

Year	Net Gereration, Billion KWH	Energy Consumed, Quadrillion Btu (10^{15}) Btu	Fuel Consumption Mix, Percent		
			Coal	Oil	Gas
1965	837	8.7	65.9	7.7	26.4
1966	928	9.7	64.5	8.6	26.9
1967	970	10.2	63.4	9.5	27.1
1968	1067	11.2	61.9	9.6	28.5
1969	1151	12.2	59.0	12.3	28.7

Source: National Coal Association

and 4 million tons of nitrogen oxides should increase to 5.60 million tons of particulates, 27.6 million tons of sulfur dioxide, and 7.1 million tons of nitrogen dioxides by FY 1977 without implementation of the Act. This projection assumes no control of sulfur dioxide and a collection efficiency of 78 percent for particulates in the base year 1967. By FY 1977, steam-electric utilities are projected to emit 64 percent of all sulfur dioxide emissions (without implementation of the Act).

Average sulfur content of coal and residual oil consumed by utilities in 1967 was 2.5 percent. Indications are that sulfur contents in these fuels have been increasing because of increased demands for low-sulfur fuels by other consumers (i.e., metallurgical coal buyers and industrial and commercial power plants) and because of the distance of the western States and Alaska from the sources of low sulfur coal. The higher trends in sulfur contents are not reflected in the projected 1977 emissions.

Implementation of the Clean Air Act would reduce particulates to 2.80 million tons and sulfur dioxide to 2.76 million tons by FY 1977. No control of nitrogen oxides is postulated.

3. Control of Emissions and Estimated Control Costs

Utilities will be able to choose among alternative control schemes in attaining SO_x emission standards. Their decisions will weigh heavily on the relative economics of the options available to them. Rather than attempt to arrive at a national cost estimate by means of delineating the option each plant would follow, the national cost was approximated using only two options. It was assumed that large plants would employ flue gas desulfurization and that small plants will employ fuel switching. This approach yields a realistic approximation of the national expenditures expected to be made by utility companies.

For power plants having a rated capacity in excess of 200 megawatts and with an overall plant load factor in excess of 30 percent, the assumed control strategy was the installation of wet limestone injection scrubbing systems to provide simultaneous control of particulates and sulfur oxides. Depending on the number and size of individual boilers within each plant, several scrubbers may be required along with a central waste disposal system. Such technology is presently being tested on a small number of existing and new installations throughout the United States. Model plant costs used in developing industry estimates for retrofitting of equipment were:

Model Plant Size	Investment Cost	Annual Cost
200 mw	$ 6.08 million	$1.77 million
1000 mw	$19.10 million	$5.83 million

All coal- and oil-fired utility plants through 1977 requiring limestone scrubbers were assumed to be built without sulfur removal equipment, and therefore would incur the retrofit costs. Federal Power Commission data indicate that the great majority of new plants built by 1975 will not have sulfur removal equipment. Costs are based on commercial availability of scrubbing. They do not take into account operational problems that are coincidental with pilot and prototype plant testing. Some recent experience with actual plant operators indicates that 150 to 200 megawatt units are experiencing costs twice the above figures, because of problems with equipment scaling, inadequate foundation support, and equipment oversizing.

Based on limestone-injection scrubbing, the steam-electric utility industry would have to invest $4.66 billion in equipment and incur an annual expense of $1.36 billion for full implementation by FY 1977. These costs are based on a 10-year depreciation schedule and 8 percent interests. These estimates apply to 100,000 mw capacity existing in 1967, with growth rates applied to estimate increase to 1977.

For high sulfur coal and for residual oil-burning power plants of less than 200 megawatts, switching to low sulfur fuels will be cheaper. These plants and their costs of compliance are discussed in Section B for small and intermediate boilers.

4. Engineering Basis of Analysis

Based on cost engineering studies of the Tennessee Valley Authority limestone scrubbing process, cost equations have been developed to calculate costs for power plants to retrofit limestone scrubbers. Generally, economic analysis shows that plants greater than 200 megawatt capacity and an operating load factor of 30 percent would be suitable to scrubbing technology.

The cost equations including the latest up-to-date unit costs revisions available within the Environmental Protection Agency for calculating investment and operating costs are as follows:

$$(1)\quad \text{Investment } (\$1000) = 27{,}307.8\,(MW) - 11.57(MW)^2 + 2358.5(S)(MW) - 1.20(S)(MW)^2$$

$$(2)\quad \text{Annual Cost } (\$1000) = L[112.67(MW)(S) - 8.33(MW)] + 1.3M[0.018\,MW + 0.595(S) + 0.0015(MW)(S) + 7.38] + 1.2W(0.36(S)(MW)) + 1.2K[0.0548(MW) - 0.00945(S)(MW) + 0.0020(MW)(S)^2] + T[(11.799MW) - 0.00536(MW)^2] + 0.23[\text{Investment}]$$

Where: MW = Megawatt rating of power plants

S = Sulfur content of fuel as a %

L = Cost of Limestone, \$2.05 per ton

M = Labor costs, \$/1000 manhours, based on \$5.00 per man-hour

W = Water costs, \$100.00 per million gallons

K = Electricity Cost (Individual Plant Production Cost), \$6000 per million kilowatt-hours

T = Cost of technical labor (professional), \$7.50 per man-hour

The above cost calculations are based on coal fossil-fired generating stations, operating at a 91 percent load factor. To determine investment costs for oil-fired installations, the sulfur content in the investment equation must be divided by 1.35, and the megawatt rating multiplied by 0.95.

To determine annual costs (A) for facilities where the load factor (LF) varies from 30 to 91 percent, the following cost correction equations were used:

If 64% $\leq$ plant factor $\leq$ 91%:

$$A_{coal} = (\text{costs @ } 91\%) \times \left[1 + (91\%\text{-}LF)\,0.00642\right] \times \left[\frac{\text{actual coal tons consumed}}{3000\,(MW)}\right]$$

$$A_{oil} = (\text{costs @ } 91\%) \times \left[1 + (91\%\text{-}LF)\,0.00642\right] \times \left[\frac{\text{actual bbl oil consumed}}{12{,}808\,(MW)}\right]$$

If plant factor $\leq$ 63%:

$$A_{coal} = (\text{costs @ } 91\%) \times \left[1.23 + (63\%\text{-LF})\ 0.0256\right] \times \left[\frac{\text{actual tons coal consumed}}{3000\ (\text{MW})}\right]$$

$$A_{oil} = (\text{costs @ } 91\%) \times \left[1.23 + (63\%\text{-LF})\ 0.0256\right] \times \left[\frac{\text{actual bbl oil consumed}}{12{,}808\ (\text{MW})}\right]$$

Where LF is plant load factor, %, in all above equations.

The requirements for limestone scrubbing were determined for a total standing generating capacity of 109,000 megawatts for the year 1967. As a matter of interest, fossil fuel-fired generating capacity of plants greater than 200 megawatts was 146,000 megawatts for the same year.

The estimation of control costs for implementation by 1977 assumes that all new plants built after 1967 were without limestone or any other byproduct recovery or sulfur throwaway equipment. Hence, these plants, included in the industry growth picture through 1977, would require the same retrofit costs as those plants existing in 1967. No allowance has been made for attrition of those plants existing in 1967.

The emissions data for particulates and sulfur dioxide are based on plant-by-plant data from the Federal Power Commission for sulfur and ash contents of respective fuels. The emission rate for sulfur is based on the premise that 95 percent of the sulfur in the fuel is liberated into the flue gas from a utility station. The estimate for particulate emissions is based on an emission factor of 18 pounds of fly ash generated per 20 pounds of total ash available in the coal. This is the performance characteristic in all pulverized coal-fired furnaces for utility stations. Emissions of particulates to the atmosphere were calculated on the assumption of a nationwide collection efficiency of 78 percent for 1967. The basis for nitrogen oxides emissions is the Esso Research and Engineering Study conducted for National Air Pollution Control Administration.

5. Impact of Nuclear Fuel Generators

As of 1970, one percent of electric utility generation was produced by nuclear reactors. Some 120,000 megawatts of light-water, nuclear reactor, generating capacity will be added during the 1971-80 period. This compares with the 200,000 megawatt capacity of fossil fuel-fired power plants. Considering the delivery lag time of nuclear plants, the high investment for nuclear reactor plants ($350 per kw versus $200 per kw for coal), and the environment problems, acceleration of new nuclear plants cannot be expected to replace any of the existing or proposed coal- or oil-fired power plants. Fast breeder reactor technology, which can utilize uranium concentrates more efficiently than light-water reactors, is not due to have any significance until the 1990's.

6. Impact on the Utility Industry

During the 1960's, the utility industry enjoyed steady fuel prices. Through increased fuel conversion efficiency, utilities were able to produce cheaper electricity. For example, the following table shows this decline in the average price per kwh for three classes of consumers (sales by privately-owned Class A and B utilities):

Year	Residential, cents/kwh	Commercial, cents/kwh	Industrial, cents/kwh
1965	2.39	2.18	1.00
1966	2.34	2.13	0.98
1967	2.31	2.11	0.98
1968	2.25	2.07	0.97
1969	2.21	2.06	0.98

Starting in 1967 with the acceleration of general inflation, increased construction costs and higher interest rates on borrowed money had an impact on the utilities. Large schedules for financing new plant capacity, high debt-to-equity ratios, and refinancing of maturing low-interest loans increased operating costs for the industry. The shortage of coal production in 1969 and 1970 raised general coal prices by 50 percent or better. Contributing factors to this shortage were shortage of skilled labor, decreased productivity at mines because of requirements of the Federal Mine Safety Act, the pessimistic attitude of the coal mining industry toward mine expansion as a result of reading too much into trends toward nuclear reactors, and the depletion of economically minable reserves in the eastern United States. Some substitution to residual and crude oil and natural gas has occurred, but supplies of gas are now so tight in many areas that any further purchases are not possible.

As a result of all these factors, increased electric rates on the order of 10 to 20 percent have been granted to some companies in recent months. It is still too early to document any price trends on the national average for the years 1970 and 1971. However, all forms of energy are expected to rise in price, including natural gas. It is doubtful that any significant substitution from electricity to other energy forms will occur.

For an individual model plant (800 to 1000 mw), expenditures of $30 per kw for air pollution control amount to 15 percent of overall plant investment. The full cost increase of 0.90 mills per kwh for pollution control compares significantly to the industry-wide fuel costs of 2.65 mills per kwh in 1967 and 2.77 mills in 1969. Capital investment ($4.66 billion) in sulfur dioxide control amounts to 5 percent of total electric utility investment projected ($90 billion) for the 1970-75 period. In this perspective, the required investment does not represent a significant impact.

7. Impact on the Consumer

The impact upon the electric power industry of full implementation would be most severe in the coal competitive regions of the United States. In these areas, the average price of a community's electric bills (a mix of residential, commercial, and industrial) would increase by 5.8 percent, based on a 1967 price of 1.56 cents per kilowatt-hour (total electrical revenues divided by kilowatt-hours sold). Regions such as California and the Pacific Northwest would be exempt from this penalty. Nationwide, the impact of implementation would call for an increase of 4.3 percent in the average price of electricity (1.56 cents/kwh).

It is anticipated that utility companies will pass on the full cost of air pollution control as rate increases. Based on past experience, utility companies have obtained increases readily from State regulatory authorities and the Federal Power Commission (having jurisdiction over intrastate and interstate utility pricing, respectively) for such reasons as more costly fuels, increased plant costs, and increased interest rates.

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IV. INDUSTRIAL PROCESSES

A. Introduction

The economic impact of the Clean Air Act of 1967, as amended, on 17 industries or industry groups is presented in this section. Coverage includes plants in operation in 1967 and additional facilities expected to be functioning by the end of FY 1977.

Industry statistics on the number of sources, capacity, production, and value of shipments for calendar year 1967 are shown in Table 4-10. Table 4-11 gives a comparision emission for FY 1967 and FY 1977, with and without implementation, along with associated costs of control. These estimates vary, sometimes significantly, from the report of last year due to revisions of emission factors and to the nationwide scope of this report. Table 4-12 presents ratios relating annual abatement control costs to capacity, production, and value of shipments for facilities operating in FY 1977. These ratios indicate the general economic impact of emission control.

For each industrial category, a detailed analysis of the financial impact of emission controls is presented. Estimates of the annualized costs and investments required to achieve compliance are superimposed on a description of the economic setting, breadth, and unique characteristics of each group. Where there is sufficient information on size, operation, and financial variables, a model plant (or plants) is constructed to show the potential impact of control costs on company operations. Emphasis is placed on the issue of whether the industry must absorb control costs or whether costs can be passed on as higher product prices. This issue is discussed in relation to the competitive patterns of the affected industry, the distribution of market strength among sellers and buyers, and the trends of prices, production, and capacity through FY 1977. When appropriate, expected changes in product price, sales, company profit, and the number and size of firms in the industry are presented.

TABLE 4-10. 1967 STATISTICS FOR INDUSTRIAL PROCESS SOURCES (NATIONAL)

Emission Source		Number of Sources	Unit of Measurement	Capacity[1] (Millions of Units per Year)	Production[1] (Millions of Units per Year)	Value of Shipments (Billions of Dollars per year)
Asphalt Batching		4,000	tons of paving mixture[2]	441	216	1.10
Cement		178	barrels	502	369	1.20
Coal Cleaning[8]		181	tons	119	93	N/A[4]
Grain: Handling		9,173	bushels[3]	5,110	10,180	N/A[4]
Milling		2,364	tons	98	49.11	4.83
Grey Iron Foundries		1,730	tons of castings[2]	17	14.3	2.70
Iron and Steel		142	tons of raw steel	165	127	13.30
Kraft (Sulfate) Pulp		116	tons	32.1	23.9	3.60
Lime		209	tons	21.1[illegible]	17.97	0.24
Nitric Acid		83	tons	8.0	6.12	0.45
Petroleum:						
Products and Storage		29,039	barrels[5]	214	1,873	22.50
Refineries		256	barrels	4,210	3,580	20.30
Phosphate		42[illegible][7]	tons P_2O_5	7.0	4.7	0.98
Primary Nonferrous Metallurgy:	Aluminum	24	tons[6]	3.5	3.3	1.56
	Copper	19	tons[6]	1.63	1.4[illegible]	1.12
	Lead	6	tons[6]	0.50	0.45	0.13
	Zinc	15	tons[6]	1.56	0.94	0.26
Secondary Nonferrous Metallurgy		55[illegible]	tons	2.8	2.[illegible]	1.48
Sulfuric Acid[9]		254	tons	38	29	N/A[4]

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[1] Capacity and production are in millions of units (tons, etc.) unless otherwise footnoted.

[2] Capacity is calculated assuming 1,000 operating [illegible] per year.

[3] Capacity is in million bushels of storage space; production, million bushels of throughput.

[4] Not applicable.

[5] Capacity is in million barrels of gasoline storage space; production, million barrels of gasoline handled.

[6] Production and capacity are given in terms of metal output and production is adjusted to remove effect of a labor strike.

[7] Excludes phosphoric acid plants.

[8] **Only 28 percent of coal cleaning plants use processes which must be controlled. That percentage of industry capacity and** production is reflected here.

[9] Includes smelter acid plants and chamber plants.

TABLE 4-11. INDUSTRIAL PROCESS SOURCES--ESTIMATES OF POTENTIAL AND REDUCED EMISSION LEVELS AND ASSOCIATED COSTS (NATIONAL)

Source	Year	Quantity of Emissions[1/] (Thousands of Tons per Year)					Associated Emission Control Level (Percent)					Control Costs (Millions of Dollars)	
		Part	SO_x	CO	HC	NO_x	Part	SO_x	CO	HC	NO_x	Investment	Annual
Asphalt Batching	1967	243					95						
	FY77 W/O[2/]	403					95						
	FY77 W[3/]	56					99					272	63
Cement	1967	813					65						
	FY77 W/O	918					92						
	FY77 W	63					99					89	35
Coal Cleaning	1967	225					58						
	FY77 W/O	162					58						
	FY77 W	9					98					21	9
Grain: Handling	1967	1,014					28						
	FY77 W/O	1,430					28						
	FY77 W	49					95					193	83
Feed	1967	256					42						
	FY77 W/O	362					42						
	FY77 W	22					95					19	5
Gray Iron Foundries	1967	217		3,200			12		18				
	FY77 W/O	260		1,800			12		18				
	FY77 W	30		240			90		93			348	120
Iron and Steel	1967	2,310					93						
	FY77 W/O	1,991					95						
	FY77 W	69					98					841	106
Kraft (Sulfate) Pulp	1967	380					85						
	FY77 W/O	536					85						
	FY77 W	8					98					132	40
Lime	1967	393					72						
	FY77 W/O	609					72						
	FY77 W	32					98					29	7
Nitric Acid	1967					153					0		
	FY77 W/O					230					0		
	FY77 W					25					90	37	14
Petroleum: Products and Storage	1967				1,038					50			
	FY77 W/O				1,349					50			
	FY77 W				296					89			
Refineries	1967	183	2,310	9,300	153		20	37	20	20			
	FY77 W/O	241	3,010	12,100	197		20	37	20	20		378	73
	FY77 W	98	21	49	17		69	100	100	95			
Phosphate	1967	260					89						
	FY77 W/O	350					89						
	FY77 W	160					95					31	15
Primary Nonferrous Metallurgy: Aluminum	1967	32					73						
	FY77 W/O	49					73						
	FY77 W	5					98					933	256
Copper	1967	241	2,580				55	19					
	FY77 W/O	314	3,335				55	19					
	FY77 W	286	535				59	87				313	100
Lead	1967	34	185				82	26					
	FY77 W/O	39	213				82	26					
	FY77 W	26	29				88	90				65	16
Zinc	1967	57	446				93	59					
	FY77 W/O	71	553				93	59					
	FY77 W	71	138				93	90				41	18
Secondary Nonferrous Metallurgy	1967	24					66						
	FY77 W/O	34					66						
	FY77 W	6					95					32	9
Sulfuric Acid	1967	25	600				45	97					
	FY77 W/O	38	920				45	97					
	FY77 W	10	170				88	100				169	39

[1/] **Emissions abbreviated are: Particulates (Part), sulfur oxides (SO_x), carbon monoxide (CO), hydrocarbons (HC), and nitrogen oxides (NO_x). Blanks in the table indicate that emission levels meet the applicable regulation (Appendix I) or that emissions are negligible or do not exist.**

[2/] Estimates without implementation of the Clean Air Act are shown.

[3/] Estimates with implementation of the Clean Air Act are shown.

[4/] Not available.

TABLE 4-12

1977 EXPECTED ANNUAL CONTROL COSTS FOR INDUSTRIAL PROCESS SOURCES RELATIVE TO CAPACITY, PRODUCTION, AND VALUE OF SHIPMENTS[1/]
(NATIONAL)

Source and Unit of Measure		Source Totals			Annual Control Cost (Millions of Dollars)	Cost Ratios		
		Capacity[2/] (Millions of Units)	Production[2/] (Millions of Units)	Value of Shipments (Billions of Dollars)		Cost per Unit of Annual Cap. (Dollars per Unit)	Cost per Unit of Annual Prod. (Dollars per Unit)	Cost per Dollar of Shipment (Percent)
Asphalt Batching	tons of paving mixture[3/]	714	357	2.1	63.0	0.09	0.18	3.0
Cement	barrels	572	477	1.6	34.6	0.06	0.07	2.2
Coal Cleaning	tons	160	125	N/A[6/]	9.3	0.058	0.074	N/A[6/]
Grain: Handling	bushels[4/]	8,548	14,360	N/A[6/]	83.0	0.006	0.01	N/A[6/]
Milling	tons	98	64.1	6.3	4.0	0.041	0.062	0.1
Gray Iron Foundries	tons of castings[3/]	20.7	17.4	3.8	126.0	6.10	7.24	3.3
Iron and Steel	tons of raw steel	203	163	17.0	306.0	1.51	1.88	1.8
Kraft (Sulfate) Pulp	tons	45.3	33.7	5.08	40.0	0.88	1.19	0.8
Lime	tons	34.43	29.27	0.41	7.2	0.21	0.25	1.8
Nitric Acid	tons	11.6	9.83	N/A[6/]	14.0	1.21	1.42	N/A[6/]
Petroleum:								
Products and Storage	barrels[5/]	278	2,435	29.25	73.3	N/A[6/]	N/A[6/]	N/A[6/]
Refineries	barrels	5,473	4,654	26.39		N/A[6/]	N/A[6/]	N/A[6/]
Phosphate	tons P_2O_5	10.0	7.1	1.48	15.0	1.50	2.11	1.0
Primary Nonferrous Metallurgy:								
Aluminum	tons	5.84	5.80	3.36	256.4	43.9	44.2	9.4
Copper	tons	2.12	1.90	2.13	100.0	47.2	52.6	4.7
Lead	tons	0.57	0.52	0.15	15.6	27.4	30.0	10.4
Zinc	tons	1.94	1.17	0.32	17.7	9.1	15.1	5.5
Secondary Nonferrous Metallurgy	tons	4.10	3.40	2.16	8.7	2.12	2.56	0.4
Sulfuric Acid	tons	43		N/A[6/]	39.0	0.91	1.18	N/A[6/]

[1/] Estimated costs for controlling particulate, sulfur oxide, carbon monoxide, hydrocarbon and nitrogen oxide emissions from facilities expected to be operating in Fiscal Year 1977.

[2/] Capacity and production are in millions of units (tons, etc.) per year unless otherwise noted in footnotes.

[3/] Capacity is calculated assuming 1,000 operating hours per year.

[4/] Capacity is in million bushels of storage space; production, million bushels of throughput.

[5/] Capacity is in million barrels of gasoline and crude oil storage space; production, million barrels of gasoline and crude oil handled.

[6/] Not applicable.

Several assumptions and approaches underly the analyses. The year 1967 was used as the data base for all industry statistics. All costs are shown in 1970 dollars. Model plants either depict industry averages or show a representative distribution of industry characteristics. Sales figures for the models are normally generated by multiplying production by 1970 average product prices. General operating and other expenses are based upon industry averages generated as a percentage of sales. Investment costs reflect not only equipment outlays but also expenses related to installation and start up. Annualized costs are the summation of three items: operating and maintenance, depreciation of the original investment, and capital costs (such as interest, taxes, and insurance) on the original investment. Depreciation was assumed to be straight line over the life of the control equipment. Unless otherwise specified, the following control equipment lives were assumed: scrubbers, 10 years; precipitators, 15 years; baghouses, 20 years. Capital charges were assumed to be 10 percent per year unless specified.

Along with other financial variables, "cash flows" and "rates of return" are intermittently presented throughout the discussions when possible. For the sake of clarity, cash flow in this report is net earnings plus depreciation and/or depletion. When compared with control costs, cash flow gives some indication of the capability of the company to meet annualized control expenses from internally generated funds. "Rate of return" is the interest rate which equates cash outflows (e.g., plant investment) with discounted cash inflows (e.g., yearly cash flows from operations). Rate of return before control, calculated for most model plants, shows the return for the plant before any abatement steps are taken. Rate of return after control is calculated assuming no product price increases. Comparison of the two provides a measure of the effect to be expected on the long run profitability of the plant if abatement costs were to be absorbed.

B. Asphalt Batching

1. Introduction

a. Nature of Product and Process

Asphalt concrete is a mixture of crushed stone aggregate and asphalt cement that is used for paving roads, driveways, parking lots, etc. In general, the crushed stone makes up about 95 percent by weight of the mixture. The material is transported by truck from the batching plant to the paving site where it is loosely spread while still hot and then compacted or rolled into a smooth surface.

At the batching plant, the following operations are performed: (1) cold aggregate is conveyed from storage bins by means of a belt and an elevator; (2) the aggregate is heated and demoisturized in a rotary kiln dryer; (3) the heated aggregate is conveyed by a bucket elevator to a vibrating screen; (4) the course and fine fractions are separated and stored in a compartmented bin; (5) weighed quantities of the sized aggregate are blended with hot asphalt and mineral filler in a paddle-type mixer; and (6) the hot mix is discharged into trucks for delivery to the paving site.

b. Emissions and Cost of Control

The primary air pollution problem in the industry is the emission of particulates from the rotary dryer. The dryer is exhausted by an induced draft fan to remove gases from fuel combustion and to remove water vapor from the crushed stone. Some of the fines in the aggregate are inevitably entrained in the exhaust. The type and size distribution of the particulate emissions vary with rotation rate, air mass velocity, feed rate, and feed composition.

Secondary sources of particulates include the aggregate elevators, vibrating screens, storage bins, weigh hopper, mixer, and transfer points. It is common practice to combine the dryer exhaust with the ventlines from the secondary sources into a single collection and fan system. Virtually all plants are equipped with cyclone collectors which economically return material to the process and also preclean the exhaust before it reaches more efficient air pollution control devices.

Particulate emissions from the industry in 1967 were estimated at 243,000 tons. If the 1967 control level of 95 percent were maintained, emissions would increase to 403,000 tons by FY 1977. The assumed process weight regulation could best be achieved through the installation of high efficiency, venturi scrubbers in smaller plants (less than 150 tons per hour capacity) and of fabric filters in larger plants (150 tons per hour or greater capacity). This would reduce emissions to 56,000 tons in FY 1977 and would require an investment of $272 million with an annual cost of $63 million in that year.

c. Scope and Limitations of Analysis

Data for this report were derived from trade associations, trade journals, Government reports, and financial documents. No trade association or Government agency tabulates statistical information for the entire industry and, therefore, information regarding industry size, production, and capacity should be considered approximate. Financial analysis was hampered by the fact that most firms are small and locally oriented in nature, causing great variations in operating parameters from firm to firm.

2. Engineering Basis of the Analysis

As previously noted, the primary air pollution problem in the industry is the emission of particulates from the rotary dryer. Secondary sources of particulates include the aggregate elevators, vibrating screens, storage bins, weigh hopper, mixer, and transfer points. Plants usually combine the exhaust from the dryer with ventlines from the secondary sources into a single fan and collection system. Cyclone collectors are normally installed to economically return fines to the process. For this analysis, it was assumed that all plants are equipped with cyclones which have a removal efficiency of 70 percent.

Table 4-13 presents a distribution of asphalt batching plants on the basis of mixer capacity. This approximate distribution was derived from knowledge of the mean capacity, the range of the capacities, and the statistical nature of the distribution. For each size classification, a calculation was made at the capacity midpoint of the efficiency required of the secondary collector (downstream from the cyclone) in order to comply with the process weight standard. To make this calculation, it was assumed that 45 pounds of particulates are emitted per ton of product.

Fabric filters and high-energy wet scrubbers have been most frequently chosen as secondary collectors. In this analysis, it was assumed that an efficiency of less than 98 percent could be achieved through the installation of a venturi scrubber, while an efficiency in excess of 98 percent would require a fabric filter. As Table 4-13 shows, this assumption means that plants with capacities of less than 150 tons per hour can be adequately controlled with venturi scrubbers, while plants greater than 150 tons per hour will require fabric filters for adequate control.

Gas volumes to be treated by the secondary control device were calculated by assuming that 215 ACFM are required for each ton of hourly production (see Reference 2).

Installed costs for venturi scrubbers were then determined based on installed costs versus gas volume relationships developed by U.S. Dept. of Health, Education, and Welfare (Publication AP-51, Figure 6-11). The highest efficiency curve was used for this application. Installed costs for fabric filters were determined from Publication No. AP-51, Figure 6-20. The cost curve representing high temperature synthetic bags was chosen.

It is estimated that there were 4,000 plants operating in 1967 and that 35 percent of these were adequately controlled. Growth in capacity is expected to average 5.25 percent for the 10-year period (1967-77). Using these figures, it was calculated that $272 million in investment would be required by 1977 with an annual cost of $63 million in that year.

TABLE 4-13. CONTROL COSTS FOR ASPHALT BATCHING PLANTS

Capacity (Tons/Hour)	% Plants	Required Efficiency (%)	Control Device	Investment ($1000)	Annual Cost ($1000)
50-100	20	96.1	Venturi Scrubber	30.0	9.4
100-150	35	97.6	Venturi Scrubber	44.0	13.8
150-200	30	98.3	Fabric Filter	82.0	15.6
200-250	10	98.7	Fabric Filter	105.5	20.0
250-300	5	98.9	Fabric Filter	129.0	24.5

3. Industry Structure

a. Characteristics of the Firms

In 1967, the industry was comprised of some 1,300 firms operating an estimated 4,000 plants. Approximately one-third of the firms operated a single plant and most of the remainder fewer than five plants.

Integration of activities varies widely from firm to firm. The following shows how firms are involved in operations supplemental to asphalt batching:

Activity	% Firms Engaged
Lays asphalt concrete	86
Contractor for road construction projects	84
Contractor for other construction projects	55
Operates gravel pit or quarry	46
Produces portland cement concrete	18
Distributes liquid asphalt	18

About 75 percent of the plants are permanently installed and the remainder are portable. Permanent plants are primarily located in urban areas where there is a continuing market for new paving and resurfacing work. Portable plants are usually involved in highway paving projects. These plants may be disassembled and relocated to shorten hauling distances as highway construction proceeds.

Plant capacities generally fall within the range of 50 to 300 tons per hour with an average capacity of 150 tons per hour. The average plant employs four persons. The trend in recent years has been toward the construction of larger plants with a greater degree of automation.

b. Operating Characteristics

Based on production and capacity figures for a 35 percent sample of plants, it is estimated that the industry operated at 49 percent of capacity of 1967. Capacity in this case was based on the normal maximum plant operation. Due to the seasonal nature of the paving business, the average plant operates 150 days per year at 8 hours per day. Inclement weather, inefficiencies in truck scheduling, time consumed in relocating portable plants, and the fact that the industry operates on a project basis are factors that contribute to the low-operating ratio in this industry.

c. Resources

The raw materials used in the production of asphalt paving are generally grouped into three classes: aggregate, filler, and asphalt. Aggregate is the mixture of course mineral material such as sand, stone, and gravel, which serves as the load-bearing constituent of asphalt paving.

Fine mineral filler consisting of either fly ash, limestone, hydrated lime, or portland cement is added to the mix to fill spaces between larger aggregate particles. The proportions of the above materials employed vary with the grade of asphalt desired for particular end uses. Asphalt cement (finally added as the bonding agent) usually constitutes 3 to 7 percent of the mix by weight.

The availability of these resources is important to the asphalt batching industry. While aggregate and fill materials are available almost anywhere, there is an acute shortage of asphalt itself, an indirect result of current efforts to control air pollution. The demand, and consequently the price, for low-sulfur fuel oil has increased markedly in the past year since it emits less pollution than coal. However, fuel oil competes with asphalt for the last fractions of crude oil, so an increasing number of suppliers are squeezing all possible fuel oil out of their crude, leaving little or no asphalt. Many suppliers have curtailed asphalt production altogether since it is economically unattractive at current market prices.

While adequate supplies of asphalt are available in the oil-producing regions--Texas, California, and adjoining States--the number of asphalt producers on the east coast has declined from eight to two. The Midwest and other regions are also experiencing shortages. Total national production has fallen below total national demand. Consequently, steps are being taken to increase import quotas on both asphalt and asphalt-rich crude oil.

In reaction to the shortage, asphalt prices have risen sharply across the country. For the Nation as a whole, the average price has increased 33 percent in the past year. The average price has risen more than 10 percent in California, where no shortage exists, but even greater price increases are essential to induce the production of sufficient asphalt to meet demand. Therefore, prices of both fuel oil and asphalt are expected to continue to rise rapidly as the enforcement of air pollution control regulations continues to increase the demand for fuel oils.

As a result of the shortage, many asphalt batching plants are being forced to reduce operations or close down completely. In certain areas, highway construction projects are being halted or slowed, and other demands are not being met. However, after the shortage is overcome, the consequent increase in asphalt prices will have little impact on the demand for asphalt paving, as asphalt constitutes only 2.5 percent of the final cost of a highway paving contract.

4. Market

a. Major Markets

Highway paving accounts for about 70 percent of the hot-mix asphalt market, parking lot paving accounts for another 24 percent, and airports and private paving make up the remainder. The interstate highway system, which has expanded rapidly during the past decade, currently accounts for 15 percent of asphalt paving consumption. Upon completion of the system, State highway departments are expected to turn their attention to secondary highway construction and maintenance which have been deemphasized during interstate construction. Thus, the loss of interstate demand should be partially compensated.

b. Competitive Products

The only alternative product to asphalt paving is portland cement. But it is 20 to 40 percent more costly per mile than asphalt paving, and consequently accounts for only 10 percent of all highway mileage. However, it has superior wear characteristics and thus has been used extensively--60 percent of the mileage--in the interstate highway system. Cement may further displace asphalt in this market if the asphalt shortage persists forcing States to contract for concrete construction. Cement is also able to compete with asphalt in the private market when special promotion campaigns are undertaken. Otherwise, upon completion of the interstate system, there will be little competition between the two products.

c. Competition Among Firms

A major limiting factor in competition between asphalt firms is the limited radius which a plant can serve due to transportation costs and the necessity of delivering the asphalt mix while still hot. Permanent plants cannot generally compete on jobs outside a radius of 50 miles from the plant. Mobile plants can, of course, move to the site of major jobs, thus increasing their potential market radius to about 500 miles.

Most highway and commercial projects are contracted on a competitive bid basis to a general contractor. While many general highway contractors own asphalt batching plants, some subcontract the asphalt concrete production to another firm, again on a competitive bid basis. In large urban areas, numerous asphalt batching firms contribute to aggressive competitive bidding. However, in small municipalities served by only one or a small number of firms, there is little competition except for an occasional large job which warrants an outside plant moving to the area.

5. Trends

Since 1961, hot-mix asphalt sales have grown at an annual rate of 6.5 percent. The industry experienced two periods of asphalt shortage in the past 10 years, during which no growth occurred--one in 1966-67 and the other in 1970-71. The interim years realized very rapid growth, expanding by 13 percent per year for 1967 to 1970.

As the interstate highway system nears completion, growth is not expected to exceed 2 percent per year at least through 1975. More rapid growth will probably resume in the long run, as the automobile population continues to grow at over 3 percent per year, requiring additional highway mileage and replacement of dirt and gravel roads.

6. Economic Impact of Control Costs

a. Impact of Plants

"Model" plants have been developed from aggregated Internal Revenue Service data to depict the financial operations of small, medium, and large asphalt batching plants before and after implementation of air pollution control. Lack of detailed data on individual plants made it impossible to determine the compatibility of the data. However, the aggregated data on model plants presented in Table 4-14 should suffice to indicate the order of magnitude of impact.

Also given in Table 4-14 are the added costs attributable to air pollution control. The range of control costs is not great,

TABLE 4-14. MODEL ASPHALT PLANT FINANCIAL ANALYSES

Operating Characteristics	Small Plant		Medium Plant		Large Plant	
	Before Control	After Control	Before Control	After Control	Before Control	After Control
Capacity (tons/hr)	68	68	134	134	194	194
Plant Investment ($\$10^3$)	78	78	126	126	134	134
Other Investment ($\$10^3$)	18	18	70	70	96	96
Control Investment ($\$10^3$)		23		56		94
Net Investment ($\$10^3$)	96	119	196	252	230	324
Sales ($\$10^3$)	154	154	474	474	668	668
Cost of Goods Sold	88	88	355	355	460	460
Control Cost	0	7	0	14	0	18
Gross Income	66	59	119	105	208	190
Administrative Cost	54	54	87	87	146	146
Income Before Tax	12	5	32	18	62	44
Income Tax	2	1	6	3	7	5
Net Income	10	4	26	15	55	39
Cash Flows	26	22	38	33	82	71
Control Cost/Ton	--	.26	--	.17	--	.15
Control Cost (% Sales)[1/]	--	4.6	--	3.0	--	2.7
% Reduction of Income	--	60	--	42	--	29
Rate of Return[2/]	20	5	17	8	28	16
ROI	10	3	13	6	24	15

[1/] Assumes an average selling price of $5.60 per ton FOB plant. Both the price and model plant data are for the year 1969.

[2/] Assumes a remaining useful life of 15 years. Fixed investment is written off on a straight-line basis at the depreciation rate indicated by the IRS data for each plant size.

varying only from $0.15 to $0.26 per ton, representing 2.7 to 4.6 percent increases in value of shipments. Such minimal economies of scale for larger plants indicate that control costs will affect plants relatively uniformly. However, these cost increases will reduce net profit by 30 percent for large firms and 60 percent for small firms if costs cannot be passed on in higher prices. Likewise, the rate of return would decrease considerably, although it would not decrease below attractive levels except for small plants.

Due to heavy depreciation charges within the industry, cash flows are reduced very little. Since depreciation represents such a major portion of cash flows, the remaining accounting life of a given plant is important. Plants near the end of their accounting lives will probably be closed and replaced with new plants regardless of size or ability to pass control cost on. Conversely, relatively new plants will probably control and continue to operate because of large cash flows.

The decision to close a plant rests not only on the remaining accounting life and the required control investment, but on the salvage value and tax writeoff attainable upon closing the old plant. Finally, the internal rate of return on an alternative investment (possibly a new batching plant) must exceed the rate attainable on the old plant after control. Such a determination must be made by each old plant considering closing. The information necessary to determine the number of plants which would close or new plants to be built was not available. However, many plants older than 10 years will probably find it economically advantageous to close.

b. Impact on Firms

For firms engaged solely in asphalt batching, the impact would be identical to the impact on individual plants. However, most firms which operate batching plants are involved in general contracting, portland cement manufacture, petroleum refining, or other diversified operations. In each case, the impact of air pollution control would be less than that for an independent batching plant, However, the extent of impact would vary with the proportion of total revenues and investment which asphalt batching plants represented.

c. Elasticity of Demand and Cost Shifting

The total demand for paving materials is determined by long-range plans for highway and commercial construction. Asphalt paving enjoys a considerable economic advantage over its only close substitute, concrete. This economic advantage will be little affected by air pollution control, as both industries incur control costs of similar magnitude. Also, since asphalt concrete constitutes only 20 to 40 percent of highway construction costs, small changes in its price will probably have little effect on demand.

In view of such relatively inelastic demand, most firms will be able to pass on the full cost of control. Firms in more isolated and less competitive areas will be able to adjust prices regardless of their control costs. In more competitive metropolitan areas, the price of hot-mix asphalt will probably reflect the average cost of control for firms within the area. Only the relatively small plants would have to absorb a portion of their control costs.

d. Impact on the Industry

An average price increase for the industry of about $0.17 per ton (3 percent) is expected. The small model plant faced with an average market price increase would have to absorb $0.09 per ton of its control cost. While this represents only a 1.6 percent price increase, it results in a reduction in profits of almost 20 percent. Such a decline in profits would not be devastating even for a small firm. However, it might reduce the income of a sole proprietor below the level at which he preferred to live, and induce him to sell the plant to a larger firm.

Although for most firms there will be no reduction in profits as a result of pollution control, many firms will experience difficulty in acquiring the necessary capital for the control investment which may be as great as 50 percent of net worth for some individual plants. Large multiplant firms and plants owned by general contractors, portland cement manufacturers, refineries, and other related industries will have little difficulty acquiring capital due to their diversity and greater financial stability. However, smaller firms having only one or two batching plants will encounter considerable difficulty unless they are very sound financially.

Both the need for capital and the cost of control will accelerate the trend toward merger and acquisition within the industry. Few, if any, new plants will close as a result of air pollution control regulations. Only those plants near the end of their accounting lives will close rather than control. Many of these, however, will be replaced by new plants, and little displacement of employees will result.

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C. Cement

1. Introduction

a. Nature of Product and Process

Portland cement, which accounts for approximately 96 percent of cement production in the United States, is a blend of various calcareous and argillaceous materials such as chalk, clay, limestone, and shale. As the binder in concrete, portland cement is the most widely used construction material in the United States and the world.

The four major steps for producing portland cement are: (1) quarrying raw materials and reducing their size, (2) grinding and blending these materials to obtain proper composition and uniformity, (3) heating the materials in a rotary kiln to liberate carbon dioxide and cause fusion, and (4) fine grinding the resultant clinker, which is sold in bulk or bagged. All portland cement is produced by either a wet or dry process with the chief difference being whether the raw materials are introduced into the kiln as a dry mixture or as a wet slurry.

b. Emissions and Cost of Control

Particulate matter is the primary emission in the manufacture of portland cement. Emission sources include: (1) raw material crushing, (2) raw material drying and grinding, (3) kiln operation, (4) clinker cooling, (5) finish grinding and packaging, and (6) various other points such as material conveyance and storage. Sulfur oxides are also formed from the combustion of fossil fuels during kiln operations, but these are mostly eliminated through combination with calcined lime within the kiln.

The raw drying-grinding mill (dry process only), the rotary kiln, and the clinker cooler are the major points of emission. Other sources are already controlled to high degrees for economical reasons as the collected material is usually returned to the process. For 1967, the portland cement industry is estimated to have controlled particulate emissions to an overall level of 91.5 percent. Emissions from the three processes considered total an estimated 813,000 tons. Rotary kilns were controlled to an average of 91 percent, raw material dryers to an average of 95 percent and clinker coolers to an average of 91 percent in 1967.

Projected growth within the cement industry would push FY 1977 emissions to an estimated 908,000 tons if the 1967 control level were maintained. With installations of fabric filters at 99.5 percent efficiency on raw drying mills, clinker coolers, and dry process kilns, and with installations of electrostatic precipitators at 99 percent efficiency on wet process kilns, it is estimated that an overall control level of 99.3 percent could be achieved reducing total emissions to 65,000 tons by FY 1977. This would require an investment of $89 million with an annual cost to the industry of $34.6 million for FY 1977.

c. Scope and Limitations of Analysis

This analysis was based on data from Government, trade, and financial reporting sources. Financial data were available for only a limited number of firms. Many firms engage in other business activities, such as the sale of readymix concrete and cement blocks, or are parts of conglomerates. Without more detailed information, it was not always possible to estimate the portion of revenues, costs, profits, or taxes attributable to cement alone in such firms. For this and similar reasons, the relationships assumed for the financial variables should be considered approximations.

2. Engineering Basis of Analysis

The three major sources of particulate emissions in a portland cement plant are the rotary kiln, the clinker cooler, and (for dry process plants only) the raw material dryer. Other sources are normally controlled to high degrees for recovery of valuable product and are not considered in this study. Emission factors for the three processes are shown in Table 4-15.

Investment and operating cost curves were developed for each of the processes to be controlled. (1) For dry process rotary kilns it was assumed that glass fabric filters would be used. Investment data were taken from Department of Health, Education, and Welfare Publication AP-51 and updated to reflect inflationary effects. (2) For wet process rotary kilns it was assumed that electrostatic precipitators would be used. Investment costs for wet process kilns were estimated by assuming a migration velocity of .35 ft/sec and a gas volume as predicted by a linear regression equation, by making use of cost data furnished by a large precipitator manufacturer. Figure 4-1 shows the resulting cost curve. Operating and maintenance cost curves for both types of kilns were estimated by using the assumptions shown in Table 4-16. (3) The assumed controls for raw material dryers and clinker coolers were glass fabric filters. For the clinker cooler it was further assumed that only the secondary section would be vented to a control system, while air from the primary section would be returned to the kiln. Investment cost curves for these two processes were updated from costs taken from Department of Health, Education, and Welfare Publication AP-51. Operating and maintenance costs were estimated by using the assumptions given in Table 4-17.

A total cost estimate for all facilities in production in 1967 was now developed by using a plant size frequency distribution for both wet and dry process plants. Costs were estimated by assuming that plants in each size category were controlled to the degrees shown in Tables 4-18 and 4-19; i.e., each plant in each frequency range requires an average investment of 60 percent of new equipment cost. For clinker coolers, it was assumed that pre-1960 plants required total new equipment costs, while plants built after 1960 required no control costs. Depreciation was assumed to be straight line over 20 years. Interest expense was estimated to be 7 percent of investment. A sample calculation for a 2.5 million barrel plant is shown in Table 4-20.

TABLE 4-15.

ASSUMED UNCONTROLLED EMISSION FACTORS

Process	Emissions
Dry Process Kiln plus Clinker Cooler	46 lb/BBL
Dry Process Dryer	12 lb/BBL
Wet Process Kiln plus Clinker Cooler	38 lb/BBL

TABLE 4-16.

O&M COST ASSUMPTIONS FOR KILNS

I. Operating and Maintenance Cost Assumptions for Fabric Filters on Process Kilns

Pressure drop, inches H_2O	-	5
Bag Material	-	Fiberglass
Air/Cloth Ratio	-	1.7
Bag Costs, $/bag	-	20
Bag Life, mos.	-	18
Annual Maintenance Costs, $/acfm-yr	-	.30
Power Costs, $/KWH	-	.012
Annual Operating Hours	-	7200
Calculated Total Annual O&M Cost, $/acfm-yr	-	.455

II. Operating and Maintenance Cost Assumptions for Precipitators on Wet Process Kilns

Pressure drop, inches H_2O	-	.75
Fan Efficiency, %	-	75
Annual Maintenance Cost, $/acfm-yr	-	.025
Precipitator power density, watts/acfm	-	.35
Power Costs, $/KWH	-	.012
Annual Operating Hours	-	7200
Calculated Total Annual O&M Cost, $/acfm-yr	-	.043

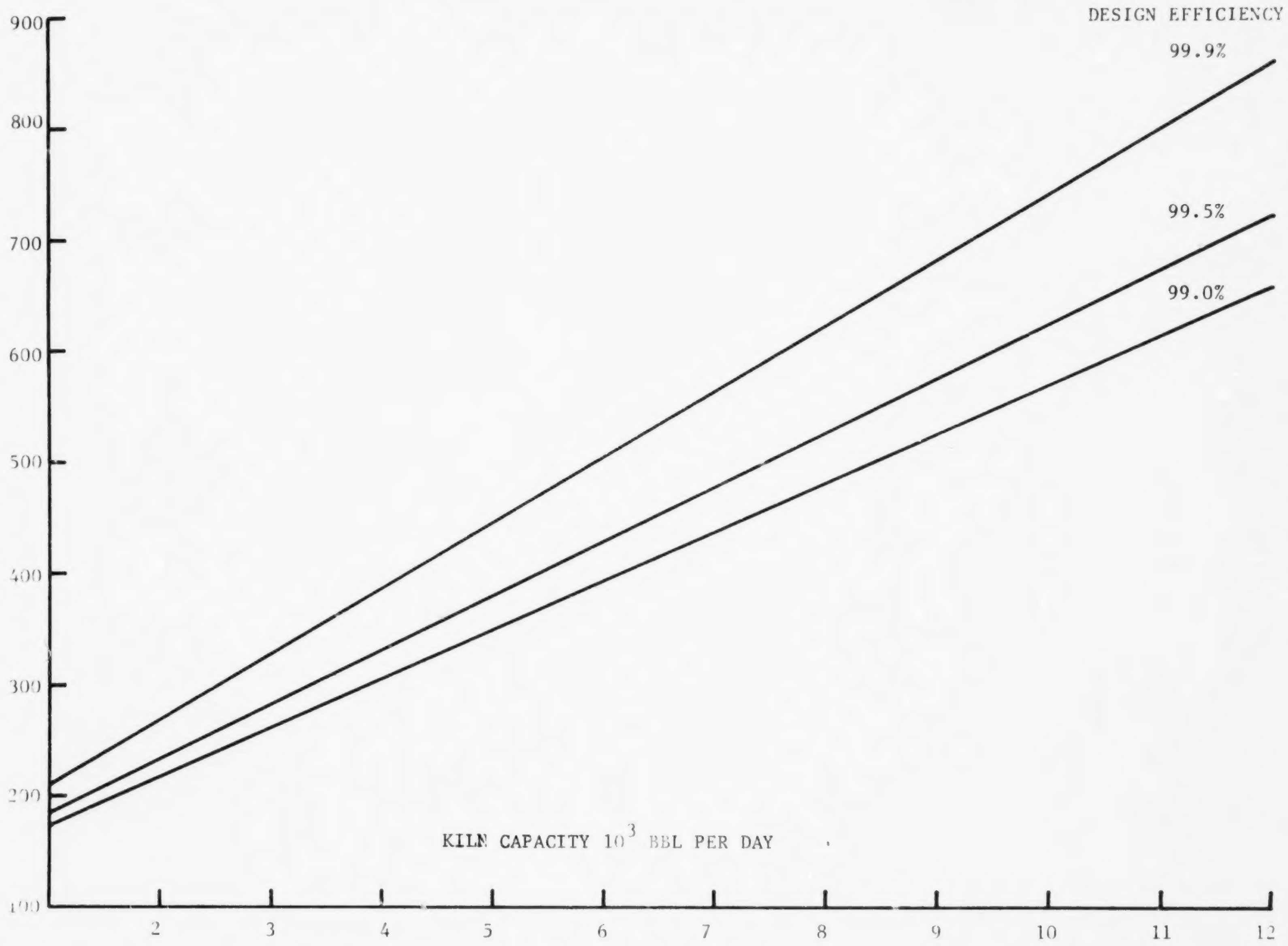

Figure 4.1. Estimated Electrostatic Precipitator Costs for Wet Process Kilns.

TABLE 4-17

O&M COST ASSUMPTIONS FOR COOLERS AND DRYERS

Pressure drop, inches H_2O	4
Air/Cloth atio	1.7
Bag Material	Fiberglass
Bag Cost, $/bag	16.50
Bag Life, mos.	24
Annual Maintenance Cost, $/acfm-yr	.24
Baghouse Air/Cloth Ratio	1.7
Power Costs, $/KWH	.012
Annual Operating Hours	7200
Calculated Total Annual O&M Cost, $/acfm-yr	.361

TABLE 4-18

1967 CONTROL LEVEL AND REQUIRED INVESTMENT FOR ROTARY KILNS

% of Total No. of Plants	On Kiln Emissions %	Required Investment as a % of New Equipment Cost
20	99	0
10	97-99.5	20
10	95-97	40
10	93-95	60
10	90-93	80
40	75-90	100

TABLE 4-19

1967 CONTROL LEVEL AND REQUIRED INVESTMENT FOR RAW DRYERS

% of Total	Control Efficiency On Kiln Emissions %	Required Investment % of New Equipment Cost
50	96-98	40
50	90-96	80

TABLE 4-20

SAMPLE COST CALCULATION FOR A MODEL 2.5-MILLION-BARREL PLANT WET OR DRY

Plant	Source	Control Device	Total Investment	Total Annualized Cost**
Process	Kiln	Fabric Filter	$552,000	$181,200
	Raw Dryer	Fabric Filter	60,000	16,200
	Cooler	Fabric Filter	95,000	46,400
			$707,000*	$243,800*
Wet Process	Kiln	E. Prec.	$565,000	$ 79,800
	Cooler	Fabric Filter	95,000	46,400
			$660,000*	$126,200*

*Based upon the average degrees of control shown in Tables 4-18 and 4-19, 60 percent of these costs were incorporated into the total cost estimates for the industry.

**Includes operating and maintenance, depreciation, and interest.

No costs were allocated to cement plants built between 1968 and 1971. This can be rationalized by considering that virtually all new facilities established between 1960 and 1967 were well controlled for various reasons--production efficiency, occupational health, State and local ordinances, and company concern for the community. Such industry self-standards were assumed to continue, and no costs were attributable to the Clean Air Act, as amended.

For plants to be built during 1972-76, compliance with Federal standards of performance for new sources would be required. To meet these standards, new wet process plants only would have to switch from precipitator to baghouse controls on their kilns. The net cost difference (baghouse control costs - precipitator control costs) was allocated to two new wet process plants estimated to begin production in each of the years 1972-76.

3. Industry Structure

a. Characteristics of the Firms

The cement industry is estimated to have 58 firms and 178 plants in the United States in 1967. Approximately 45 percent of the firms operated more than one plant, and approximately half of those firms had capacities of over 10 million barrels of cement per year. In recent years there has been a significant increase in the rate of integration, mergers, and diversification among firms to reduce their dependence on the cyclical cement and construction business.

Cement plants in recent years have added large kilns, computerized their operations, and improved integration of equipment to increase operating efficiencies. The range of capacities for all plants listed in operation in 1967 was from 0.5 to 16 million barrels per year, with the average plant having a capacity of approximately 2.5 million barrels per year.

b. Operating Characteristics

The United States capacity for the cement industry was 502 million barrels in 1967. With production at 369 million barrels, the industry operated at 73.5 percent of capacity. Operation at 85 to 90 percent tends to produce maximum profits, but the industry has operated between 70 and 80 percent of capacity over the past 10 years and has been faced with a chronic excess capacity.

c. Resources

The raw materials used in manufacturing cement are abundant and widely dispersed throughout the country, and material costs are stable because most companies own their sources and have ample reserves. However, the rising costs of fuel, labor, and transportation, the other major cost variables, in recent years have coupled with an inability to raise prices proportionately and accounted for the generally below-average profit of this industry.

Labor accounts for approximately 20 percent of total cost. Producers have tried to reduce labor costs by switching to higher capacity equipment combined with automated computerized controls. Although output has regularly increased, the number of employees, particularly production workers, has steadily decreased. As of 1967 the cement industry employed 32,400 people, down from 39,400 in 1960.

4. Market

a. Distribution

Since raw materials for cement production are widely distributed throughout the country, cement plants generally locate close to major markets. Normally, cement is not shipped more than 200 to 300 miles from the plant, because transportation costs tend to price a firm out of more distant markets.

Cement sales are historically related to construction activity; therefore, the performance of the cement industry will be set by the general performance of the construction industry. Cement purchases represent about 1 percent of the dollar inputs of the construction industry, based on the 1963 input-output relationships. The distribution of cement sales by purchasers for 1967 was:

Ready-mixed concrete producers	60%
Concrete product manufacturers	13%
Highway contractors	10%
Building materials dealers	8%
Other contractors	5%
Miscellaneous users (including Government)	4%

b. Competition

Portland cement is a standardized product; thus competition among sellers depends on small price differentials within a clearly defined price pattern. Most customers can choose among a number of cement producers, and price shading and partial freight absorption by the producers may be necessary to clinch a sale. This competitive pressure has caused many firms to close their less efficient plants or to modernize them in order to maintain profits.

External competition in general does not cause extensive pressures (see Asphalt Batching--Competitive Products). However, for some uses (building and structural materials), the consumer has considerable choice, and cement does compete with brick, steel, and aluminum. Foreign trade has never assumed much national importance. Imports and exports of cement account for less than 5 percent of the United States market and are significant only in markets on the Atlantic Coast and the Canadian border.

5. Trends

a. Capacity and Production

For over a decade the cement industry has been plagued with overcapacity. However, producers have begun to achieve a better operating ratio and this is expected to continue through the seventies. For the next five years, net capacity should grow at a rate of 1 to 2 percent per year.

Production and shipments have been increasing on an average of 2.2 percent yearly. 1970 was a discouraging year--actual shipments decreased 5 percent to 388 million barrels from the record 1969 total of 407.5 million barrels. Prospects look better, and most companies are beginning to report optimism as construction activity increases. Growth of both production and shipments from the cement industry over the next 5 years should approximate 3 percent per year.

b. Price, Sales, and Profits

Prices declined slowly from a 1961 average level of $3.35

per barrel at the mill to $3.05 per barrel in 1966 but have since risen gradually to $3.25 in 1970. Less than optimum operating ratios, a slowly growing market, and competition with other building materials will probably keep prices rising at a slow rate through 1977. Profits are expected to show improvement, and prospects for 1972 and later look reasonably optimistic.

6. Economic Impact of Control Costs

a. Industry Composite

Plants built since 1960 have, almost without exception, been equipped with high efficiency control equipment. It is the older plants, therefore, that will feel the greatest effects of the costs for air pollution control. It is estimated that by 1967 the portland cement industry had already invested approximately $50 million in equipment for control of kilns, raw mills, and clinker coolers and was experiencing an annual cost of $18 million.

b. Impact on a Plant

The impact of the additional cost of air pollution control is developed using "model" plants, constructed to represent typical operating patterns. The plants described (Table 4-21) do not actually exist, but are based on average characteristics within the industry.

The relationships shown in Table 4-21 indicate the magnitude of air pollution control costs for both a wet and dry process "model" plant of average capacity. The "model" assumes no preexisting partial control. Therefore, full costs are shown. These cost figures indicate the impact which may be expected for single-plant firms. The above costs have also been calculated without giving credit for recovered materials. Such an allowance is difficult to estimate, but should, in the normal case, produce some savings.

c. Impact on the Firm

The majority of cement manufacturers are conglomerates in the building materials industry, deriving income from broad product lines including concrete blocks, piping, wallboard, and related items. Pollution control costs will hamper earnings, but the effect will be diluted for most firms because of their diversification and a brighter outlook for the whole industry.

TABLE 4-21. BASIC DESCRIPTIONS AND INCOME STATEMENTS FOR MODEL CEMENT PLANTS

"Model" Plants (Wet and Dry Process)	
Capacity (Thousands of BBL per year)	2,500
Kilns (Number and Size)	1-520 ft.
Plant Construction Cost, Without Control, 1967	$16.7 mil.
Production (Thousands of BBL per year)	2,000
Average Mill Price per BBL	$3.25
Control Investment, Wet Process	$0.660 mil.
Annualized Control Cost, Wet Process	$0.126 mil.
Control Investment, Dry Process	$0.707 mil.
Annualized Control Cost, Dry Process	$0.244 mil.

Income Statement
(Thousands of Dollars)

	Without Control Wet and Dry	With Control Dry Process	With Control Wet Process
Sales	$6,500	$6,500	$6,500
Cost of Goods Sold	5,543	5,543	5,543
Added Control Cost	0	244	126
Net Income Before Tax	957	713	831
Income Tax	431	321	374
Net Earnings	526	392	457
Cash Flow	1,194	1,095	1,158
Net Earnings/BBL	$0.263	$0.196	$0.229
Cash Flow/BBL	0.597	0.548	0.579
Control Cost/BBL	0	0.122	0.063
Rate of Return	5.08%	3.34%	4.40%

Although capital requirements are increased roughly 5 to 10 percent per new plant installation due to particulate control, it appears that the capability of most firms to raise necessary capital has not diminished. Most firms have continually invested substantial amounts of money in modernizing and replacing outmoded facilities, and they should be able to continue to do so in the future.

d. Demand Elasticity and Cost Shifting

To the extent that demand for cement is derived from the demand for public and private construction, which is not highly elastic with regard to price, the overall demand for cement would not be very sensitive to small price changes. In recent years cement has had a fairly advantageous price position relative to competing building materials, and price increases for cement and cement products may effect substitution somewhat. However, cement is a basic, unique product, and the cement industry should lose little of its market in the construction area, assuming the added control costs are passed on.

Within the industry, an attempt by some firms to raise prices as a means of shifting control costs would almost certainly lead other cement firms to move into the market. The market for any one firm is usually small geographically. Selective price increases in some local markets will encourage large firms to expand their selling radii.

For the past decade, demand for cement has fallen short of supply. Competition for sales has been stiff, prices have been low, and consequently air pollution control costs have generally been absorbed by the industry. For the future, however, demand is expected to increase, and prices should rise.

Average control cost per barrel amounts to \$.07, indicating a price increase of 2.2 percent based upon an existing price of \$3.25 per barrel. With a favorable outlook, it is expected that by

1977 the cement industry in general should be able to shift most of this control cost into product prices.

e. Effect on Industry

Many individual plants are still obsolete from both an operating and a pollution point of view. Many of the older plants are estimated to have labor costs per barrel 3 times that of the newer (usually computerized) mills. Strict enforcement of pollution legislation and regulations could cause closings in the years immediately ahead.

Pollution control has proceeded at a rapid rate within the industry during the past several years. 1970 set an all-time record when at least 17 precipitators and 7 baghouses were installed, most of them on kilns. There was also a sharp increase in the number of smaller collectors added. These expenditures are purely costs of production and do affect earnings, but in no case does it appear that these costs alone have caused or will cause a firm to fail.

The cement industry has made considerable progress in combatting several of its major handicaps. There should be an appreciable increase in shipments in the immediate future. Price increases made early in 1970 held up fairly well throughout the country. Overcapacity has been lessening and there should be good improvement in the production/capacity ratio. Pollution control, then, may hold down industry growth and profits to some extent, but the effect is expected to be small.

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D. Coal Cleaning

1. Introduction

a. Nature of Product and Process

Coal cleaning removes undesirable materials such as sulfur compounds, dirt, clay, rock, shale, and other inorganic impurities from raw, mine-run, bituminous and anthracite coal. Cleaning improves the quality of the coal by reducing ash and sulfur content and increases the Btu output per pound of coal.

Coal cleaning may be accomplished by washing with air or water. Air washing is generally done in pneumatic cleaners. Wet washing techniques sometimes use thermal driers to decrease the moisture content of the final product. Approximately 7 percent of the coal cleaned in the United States is produced in pneumatic cleaners; the remaining 93 percent is cleaned by wet washing. Approximately 21 percent of the wet washed coal is dried in thermal driers--predominately the flash or fluidized-bed type.

b. Emissions and Cost of Control

Particulates in the form of dust are the major emission from coal cleaning plants. Emissions result from handling, cleaning, and drying operations. The major emission sources are the thermal driers and pneumatic cleaners.

Available data on the current level of control indicate that 87 percent of the thermal coal driers and 16 percent of the pneumatic cleaners are controlled at an efficiency of 80 percent, resulting in a composite control level of 58 percent for the industry. At this control level, it was estimated that 1967 emissions totaled 225,000 tons. If that level were maintained through 1977, the estimated total would be 342,000 tons. With the application of venturi scrubbers to thermal driers and pneumatic cleaners, it is estimated that an overall control level of 98.4 percent would reduce 1977 emission to 9,300 tons.

Because of the coal dust content of the off-gases from coal cleaning, a fire and explosion hazard exists. For these reasons, wet scrubbers rather than baghouses are the preferred control devices. Venturi scrubbers of 20-, 15-, and 10-inch pressure drops were assumed for fluidized-bed driers, flash driers, and pneumatic cleaners, respectively. Due to the sulfur content of the particles collected, it was assumed that these scrubbers would be of stainless steel construction. With these assumptions, it was estimated that an investment of $21 million would be required by 1977 with annual costs of $9.3 million.

c. Scope and Limitations of Analysis

Although there is a relatively large number of coal cleaning plants in the United States, data on plant locations, capacities, and production are available. However, it was not possible to determine the coal cleaning process used in each plant. For this reason, cleaning plants were grouped according to size, average values were applied to production and capacity, and control costs were based on model plants for each size range. Financial and market data for the industry were fairly complete.

2. Engineering Basis of Analysis

Coal is cleaned by both wet and dry methods. In this analysis only the three predominant processes within the coal cleaning industry were considered: flash and fluidized-bed thermal driers (for coal cleaned by wet methods), and pneumatic cleaners. These three processes are significant sources of particulate emissions mostly in the form of coal dust. Uncontrolled emission rates from these three processes are shown in Table 4-22.

Available data on the current level of control show that 87 percent of both types of thermal driers and 16 percent of pneumatic cleaners are controlled at an efficiency of 80 percent. Almost all pneumatic cleaners and 50 percent of the thermal driers are equipped with cyclones, 49 percent of the thermal driers have cyclones plus low energy scrubbers, and 1 percent of the thermal driers have cyclones plus high energy scrubbers. The composite level of control in 1967 was estimated to be about 58 percent.

To comply with the process weight standard and an opacity regulation, it was estimated that flash driers, fluidized-bed driers, and pneumatic cleaners would have to be controlled at efficiencies of 99 percent, 99 percent, and 97 percent, respectively. These efficiencies are based on a grain loading requirement of 0.03 grains per standard cubic foot of exit gas.

Due to fire and explosion hazards of off-gases from coal cleaning, wet cleaning devices are the preferred control devices. For this study, venturi scrubbers were assumed for each of the cleaning processes. Estimated gas volumes and assumed controls for the processes are shown in Table 4-23.

With the assumptions in Table 4-23 and the cost curves shown in Figures 4-11 and 4-12 (Subsection L, Phosphate Industry), investment cost curves for the three processes were developed. Installed costs were taken at 250 percent of the equipment costs for the three processes. Table 4-24 shows investment costs as a function of plant size.

Operating costs for the assumed control devices were estimated by assuming that the annual operating time for the equipment would be 3750 hours per year (2 shifts per day, 7.5 effective hours per shift, 5 days per week, and 50 weeks per year). Total annual operating costs, including capital charges are shown in Table 4-24.

In order to make a national estimate of control costs for coal cleaning it was assumed that all existing high-energy scrubbers were placed in service after 1967. Thus the cost estimate given represents the total cost to the industry.

A national cost estimate was determined by grouping all plants into size categories according to production capacity. By knowing the total number of plants and total production capacity for each size category, a model plant of average size was determined. Cost estimates for each size category were then made by assuming that 7.1 percent of the plants used pneumatic methods with the remaining plants using wet wash methods. It was further assumed that 21 percent of the wet cleaning plants made use of thermal driers with 56.5 percent of the driers being of the flash type and the remaining 43.5 percent

TABLE 4-22

UNCONTROLLED PARTICULATE EMISSION RATES FROM COAL CLEANING PROCESSES

Process	Uncontrolled Emissions (lb/ton coal feed)
Flash drier	16
Fluidized-bed drier	20
Pneumatic Cleaner	3

TABLE 4-23

ESTIMATED GAS DATA AND SELECTED CONTROLS

Process	Temp. To Collector °F	Initial Prod. Moisture %	Final Prod. Moisture %	Gas Volume acfm/ton per hour	Selected Control Equipment
Flash Drier	250°F	10.5	2.8	576	15" W.G. Venturi
Fluidized-bed Drier	159°F	10.5	2.8	480	20" W.G. Venturi
Pneumatic Cleaner	Ambient	N.A.	N.A.	357	10" W.G. Venturi

TABLE 4-24

COST REQUIREMENTS ($1000's) FOR THREE COAL CLEANING PROCESSES BY PLANT SIZE

Plant Capacity, Tons Per Hour	Fluidized Bed Driers		Flash Driers		Pneumatic Cleaners	
	Investment	Annual	Investment	Annual	Investment	Annual
40	34.0	16.8	37.0	17.0	28.0	10.1
100	57.0	35.0	62.0	36.4	50.0	21.5
200	140.0	73.0	160.0	77.0	74.0	36.8
500	275.0	145.0	330.0	153.0	220.0	93.0

being of the fluidized-bed type. The total cost estimate was then determined by summing the costs for each size category and adding costs due to growth between 1967 and 1977.

3. Industry Structures

a. Characteristics of the Firms

Coal cleaning is an integral part of the coal-mining industry. Although currently there are approximately 5,300 active coal mines controlled by approximately 3,800 firms, the majority are small operators. During recent years, the trend has been to larger mines and consolidation of companies into relatively large groupings of mines to effect greater efficiencies in management, mechanized operation, and marketing. The concentration of industry production in the largest operating groups can be seen in Table 4-25. In 1967, the coal industry produced 553 million tons of coal having a value of shipments of $2.6 billion.

TABLE 4-25. NATIONAL PRODUCTION OF LARGER COAL FIRMS

Operating Groups	Percent of National Production
largest 50	69
largest 15	52
largest 2	22

Generally only the larger mines and operating groups undertake coal cleaning. Consolidation of the production from one large mine or a group of neighboring mines into one large cleaning plant is so prevalent that the 471 plants which existed in 1967 processed 81 percent of all raw coal mined. (The Minerals Yearbook for 1967 reports the production of 334 million tons of cleaned coal or 62.3 percent of the total tonnage mined. However, 81 percent of all raw coal that underwent cleaning yielded 17.8 percent refuse.) The distribution of outputs indicates that the largest plants again account for a disproportionate share of total output (Table 4-26).

TABLE 4-26. SIZE DISTRIBUTION OF COAL CLEANING PLANTS

Plant Output Range Tons/Year	Percent of All Plants	Percent of National Production
>1,500,000	7	30
500,000-1,500,000	23	39
100,000-500,000	50	27
<100,000	20	4

Most of the thousands of small mines and mining companies which produce less than 100,000 tons per year undertake little or no coal cleaning. At most they may sort coal by size, but frequently it is sold "mine run" or unsorted.

b. Resources

About two-thirds of the U.S. coal reserves are low sulfur. Unfortunately, less than 10 percent of the known reserves of low sulfur coal lie east of the Mississippi, and a large portion of that is earmarked for special use such as making metallurgical coke.

Transportation is the largest element in the cost of coal to the consumer, on average exceeding the value of coal at the mine. Labor costs are the second largest element of cost amounting to 40 percent of the FOB value of coal. Labor costs have risen more rapidly than any other cost element and are projected to increase further.

4. Market

a. Major Markets

Table 4-27 presents the major markets for coal, the proportion of coal consumption for which each accounts, and the proportion coal represents of the value of shipments for each sector.

TABLE 4-27. MAJOR MARKETS FOR COAL

Market Sector	% of Total Coal Demand	Coal as % of Sector Value of Shipments
Electric Utilities	59	35
Steel	19	4.5
Chemicals	4	<1
Pulp and Paper	3	<1
Cement	1	5.5
Other Domestic Sectors	4	-
Exports	10	-
Total	100	

The largest and fastest growing market for coal is the electric utility industry. The electric industry utilizes over half of the coal production, and coal accounts for almost 35 percent of the value of the electric power produced. The second largest market, steel, utilizes 19 percent of coal production, but coal comprises only 4.5 percent of the value of steel production. In only one other major market does coal comprise more than 5 percent of the value of shipments--cement industry--where about 5.5 percent of the input is coal.

Coal is essential to production in both the electric power and steel industries to such an extent that many firms in these industries own coal companies to provide their supplies. Long-term contracts, some as long as 20 years, are also used for this purpose.

b. Competitive Fuels

As the basic uses of coal are for heat and power, it has faced competition in all of its markets from other energy resources. Principal among the competitive energy resources are fuel oil, natural gas, and nuclear power. In large-volume commercial markets coal has to compete intensively on the basis of price, efficiency in utilization, and convenience.

Despite a continued increase in the demand for coal, its share of the total energy market has declined substantially reflecting the increasing interchangeability among energy sources. Recent air pollution regulations requiring the use of low sulfur fuels have accelerated the utilization of both natural gas and low sulfur fuel oils, especially by most small users who cannot employ stack gas cleaning methods. However, the rapidly rising cost of these alternative fuels, their limited supply and the high cost of conversion are expected to restrict further growth by these fuels.

Nuclear power generation has the greatest potential for providing low cost electrical energy in the future. At this time, however, nuclear power contributes less than 1 percent of the Nation's electric generating capacity.

The extent of utilization of alternative fuels varies greatly by region. The region east of the Mississippi accounts for 80 percent of all coal consumptions, whereas, the Southwest and Pacific coast regions produce negligible amounts of coal and rely almost entirely on natural gas or oil. West North Central States produce and consume small amounts of coal, with over half of their consumption being imported from the Eastern region.

c. Competition Among Sellers

The concentration of an industry's output in a few large firms tends to create an oligopolistic market where individual firms can influence market price. Firms in such industries may either consciously collude on price levels or follow the price levels established by one or more leading firms or trade associations in the industry. Failure of such overt or tacit price agreements frequently leads to open price warfare during periods of slack demand, driving prices down to unprofitable levels.

The coal industry to a large degree faces an oligopolistic market in which competing firms face a kinked demand curve. Small upward price changes generally result in large tonnage shifts away from the firm that is raising prices. Below the going price, a firm's demand curve is inelastic; that is, lower price offers are met by competitors anxious to retain their market shares. The industry has largely overcome its price-cutting practices of the fifties and tends, within each regional market, to conform to price levels established by the major producers or associations.

However, the sizeable number of large firms and many competitive small firms within the industry insure a considerable degree of competition within the industry. The bargaining strength of large industrial and utility consumers as well as the availability of alternative fuels lends further competition to the market.

5. Trends

a. Price Trends

Rising costs of labor and materials, largely compensated by increasing productivity during the late fifties and early sixties, resulted in an actual decline in the price of coal. By 1967, expanded utilization of continuous mining and mechanical loading in underground mines, and increased application of surface mining had increased output per man-day from 6.8 tons in 1950 to 19.2 tons. However, no further breakthroughs in technology are expected which would enable productivity to keep pace with increases in costs. In fact, the average price of coal reversed its downtrend in 1963 and had risen from $4.39 per ton to $6.20 in 1970.

The most significant factor affecting future coal prices is the Mine Health and Safety Act of 1969, whereby mines can be closed down if they do not comply with safety standards. The imposed standards will not only require considerable investments in safety equipment and supplies but will require far more rigid operating practices, which will result in reduced productivity, at least in the short run. Coal prices are expected to rise by $1.50 to $2.50 per ton as a direct result of compliance with the new regulations. On the basis of these mine safety costs and projections of current trends in labor, material, productivity, and other cost factors, the price per ton of coal in the year 1980 is expected to be $9.55 compared to $6.20 in 1970.

b. Demand Growth Trends

The demand for coal has been projected by the Bureau of Mines through the year 2000 to reflect the range of possible growth rates for each market sector. The range of compound annual growth rates for coal demand is from 3 to 5.3 percent. The high demand forecast reflects the production of large volumes of synthetic gas from coal, the solution of air pollution problems related to coal burning, and severe limitations on the supplies of alternative fuels. None of these assumptions applies to the immediate future. Instead, the role for coal is likely to be curtailed during the next 5 years by sulfur content restrictions. Replacement of high sulfur coal with low sulfur coal from western mines will require new mine developments and the expansion of coal transportation facilities. Fuel costs, even to midwestern utilities, will increase substantially. Other approaches to the clean utilization of coal, gasification and stack-gas cleaning are now being developed, but are at least 5 to 10 years from widespread commercial applications. The lower growth forecast is therefore more relevant to the conditions of the time period through FY 1977.

c. Production Trends

To meet a 3 percent annual growth rate in demand, the coal industry would have to increase production to 610 million tons by 1977. At the 1970 average price of $6.26 per ton, the value of shipments would be $3.8 billion.

Capacity will have to be increased at an even faster rate than demand growth since requirements for low sulfur coal have significantly reduced the available productive capacity and will in time precipitate further reductions by effectively closing high sulfur mines as regulations become more widespread.

Coal desulfurization through extensive cleaning may be more widely applied to reduce the sulfur content of coal from existing mines and to thereby retain their productive capacities. However, desulfurization is limited to those coals which are of sufficiently low sulfur content (<1.5 percent) and high washability to be cleaned below the 1 percent sulfur level. Less limited cleaning techniques have yet to be developed. Only after commercial development of stack-gas cleaning devices will many high sulfur coal mines again be productive. In the short run, development of new low sulfur coal reserves is essential.

More conventional coal cleaning practices will continue to be employed due to the economic benefits to be derived through increasing the Btu content of coal. The percentage of coal cleaned has declined since 1965 from 63.7 to 59.7 percent in 1969, and yet the absolute tonnage of raw coal undergoing cleaning has not declined significantly. Whether the recent downtrend represents a reversal of the long-term trend of expanding coal cleaning or whether it is merely a short-term adjustment is uncertain. Therefore, for purposes of this analysis, it is assumed that coal cleaning will account for approximately a constant share of total coal production.

Because of the trend of consolidation in the industry, coal cleaning will be carried out by fewer but larger plants. The total number of coal cleaning plants has declined from 535 in 1960 to 435 in 1968, while the annual tonnage of coal cleaned increased from 270 to 335 million short tons.

6. Economic Impact of Control Costs

a. Elasticity of Demand and Cost Shifting

The demand for coal is derived from the demand for the end products in which it is used. As a result, changes in coal prices have little effect on the demand for coal. The extent this relatively inelasticity prevails depends on the markets under consideration. Demand is less price-inelastic in utility markets than in manufacturing industries where coal costs represent a smaller percentage of total production costs. Cross elasticities among alternative fuels are moderately high, but they are modified by the increasing scarcity of natural gas and fuel oils, and by contract arrangements that distort the picture.

b. Impact on the Industry

Control costs are incurred by only 28 percent of all coal cleaning plants--those using pneumatic cleaning or thermal drying. Also, since coal cleaning is undertaken predominately by large mines and consolidated corporations, the many small mines and mining companies within the industry are unaffected.

The average control cost per ton of coal is only 7.4 cents or 1.2 percent of the average 1970 market price of $6.20 per ton. This is insignificant compared to the cost increase associated with the Mine Safety Act, and is less than the average annual increase in labor costs. The coal industry should be able to easily pass on these additional costs, especially in view of the relatively inelastic total demand for coal.

Even the relative competitive position of firms should be little affected, as control costs are only 7 and 12 cents per ton for the largest and smallest size plants, respectively. Large plants realize some economies of scale in air pollution control costs, but the differential will have little impact on the trend toward fewer and larger cleaning plants.

The investment required to open a new optimum size mine is $10 to $20 million. The requirement of an additional investment of $200,000 for control equipment will hardly inhibit the development of new mining capacity.

Of far greater significance to the coal industry are the recent restrictions imposed by many States on sulfur content of fuels. In such States consumers of high sulfur coal will find it necessary to switch to alternative low sulfur fuels until stack-gas cleaning can be employed. The markets of many high sulfur coal mines will thereby be restricted or even eliminated, forcing them to close. Many intermediate sulfur coal mines will have to implement more extensive and costly coal cleaning technologies to desulfurize their coal sufficiently. Since existing low sulfur mines and coal cleaning technology cannot meet the growing demand for low sulfur coals, the restriction of supply will result in higher prices of coal and consequently greater profits for surviving mines.

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E. Grain Handling

1. Introduction

This section will focus upon country and terminal elevators. Elevator operators have the responsibility for handling, cleaning, and storing of grains, and provide the distribution link between the farmer and various grain processors or the export market.

Two processing industries, flour milling and feed milling, were also surveyed but will not be discussed extensively. Emissions from flour production are well controlled and will not need a significant additional cost outlay. Modern flour mills are normally flanked by a battery of wheat elevators, which can be a pollution source, so these storehouses have been included in the terminal elevator category. The formula feed industry is covered only in the section concerning emissions and cost of control. The industry will require additional particulate abatement, but the cost burden involved is small and the economic impact upon prices and industry earnings is minimal. Briefly, to meet the assumed standards an average control cost of 8.4 cents per ton of feed is expected. This amounts to only 0.1 percent of a precontrol 1970 selling price of nearly $84 per ton. Such a small cost increase should eventually be passed on to the consumer.

a. Nature of Product and Process

The bulk of cash crops (normally wheat, corn, oats, barley, rye, or soybeans) is transported from the farm to the country elevator operator. Grain is unloaded from farm trucks, weighed, inspected, and transferred to a storage bin. Once a buyer has been found, the grain is loaded (normally by spouting) into a prepared railroad car, truck, or barge. The function of the elevator is not primarily to store, but to hold the grain until a market can be found in the large centers of accumulation--at processing plants, large mills, and terminal elevators. The physical process is quite simple.

If the grain is not sold to a local mill, exporter, or other outlet, it is transferred to the terminal elevator operator. Terminals are very large elevators generally located at significant grain trade cities. The function of a terminal merchant is to store the grain without deterioration in quality and to bring it to commercial grade so as to conform to the needs of buyers. Handling parallels that at the country location, but terminal merchants are the first to thoroughly clean, dry, separate, and store the grain at proper temperature and humidity. Grain moving out from terminals is ultimately used for food, feed, export, or industrial purposes.

b. Emissions and Cost of Control

Large quantities of particulates are airborne during the handling of grains, principally due to mechanical abrasion between kernels and the loosening of adhered dirt from the field. Because operations are normally located in rural areas, there has historically been little emphasis placed on air pollution control practices which exceed the level required for economical recovery of materials, reduction of explosion hazards, and general good housekeeping. Consequently, low efficiency cyclone separators have been the most commonly employed control devices in the industry.

For this analysis, it has been assumed that country elevators are only responsible for unloading, weighing, storing, and loading grain and that terminal elevators do the cleaning, drying, blending, and occasional turning to prevent deterioration. From these assumptions, particulate emissions from both elevator types were estimated to be 1,014,000 tons in 1967, and if the 1967 control level of 28 percent were to be maintained, emissions would increase to 1,430,000 tons by 1977. The assumed process weight limitation could best be achieved by the installation of fabric filters; such practice would reduce 1977 emissions to 99,000 tons and would achieve a control level of 95 percent. The investment cost is estimated to be $395 million with an annual cost of $83 million in that year.

Thorough cleaning, dehydration, grinding, blending, and pelletizing occur at formula feed mills along with extensive conveyance of materials. These operations generate dust. Particulate emissions were estimated to be 256,000 tons in 1967. If the 1967 control level of 42 percent were maintained, emissions would reach 362,000 tons by 1977. Fabric filters are assumed to be the most feasible means of achieving the process weight code; this would reduce 1977 emissions to 22,000 tons at an investment of $19 million and an annual cost of $4 million for that year for a control level of 95 percent.

c. Scope and Limitations of Analysis

This analysis was based on data available from Government, trade, and financial reporting sources. Because of the large number of firms involved in grain handling, data descriptive of industry size, production, and capacity should be considered approximate. Separation of country from terminal elevators was accomplished by dividing elevator capacity data above and below the 1-million-bushel point. Cash grain prices and operating results vary widely, and the relationships assumed for financial variables should be considered averages.

2. Engineering Basis of the Analysis

A distribution of grain elevators on the basis of capacity was available from the Department of Agriculture for the year 1967 and appears in Tables 4-28 and 4-29. For this analysis, elevators with capacities less than one million bushels were defined as country elevators, while those with capacities in excess of one million bushels were defined as terminal elevators, with the exception that there were 251 terminal elevators identified with capacities ranging from 750 thousand to one million bushels.

Country Elevators:

For the purpose of this analysis, country elevators are assumed to unload, weigh, store, and load grain. All of these operations give rise to airborne particulates and a total emission factor of 8 pounds per ton was assumed. Control costs were based on installing a single fabric filter system to control all operations.

In Table 4-28, the average production rate for each size range was computed by assuming that the annual throughput of the average elevator was 220 percent of the capacity and that the average elevator operated 2500 hours per year. Thus, the average production rate was calculated by multiplying the midpoint of the capacity range by 2.2 and dividing by 2500 hours. The gas volume to be treated was determined by assuming that 60 ACFM are required for each bushel per hour processed [quoted by Cargill Corporation]. The investment for installation of a fabric filter system was computed using a factor of $2 per cubic foot per minute (cfm) of gas handled. The following assumptions were used in calculating the annual cost:

Depreciation: straight line over 20 years,
Interest: 10 percent of investment,
Operating & Maintenance: 6 percent of investment.

The total investment and annual costs computed from Table 4-28 were inflated by an estimated 2 percent annual growth rate to arrive at the 1977 estimated investment requirement of $271 million with an annual cost of $56.9 million in that year.

Terminal Elevators:

In addition to the functions performed by country elevators, terminal elevators clean, dry, blend, and occasionally turn the grain to prevent deterioration. An emission factor of 14 pounds per ton of grain processed was assumed for these elevators.

Table 4-29 presents the calculation of control cost requirements for terminal elevators. In this case, it was assumed that annual throughput was 150 percent of capacity and that the average terminal elevator operated 8,000 hours per year. Because of the additional operations performed, the gas volume requirement was assumed to be 90 ACFM for each bushel per hour processed. The cost factors and growth rate applied were the same as those used for country elevators.

The 1977 investment requirement calculated was $124 million with an annual cost of $26 million in that year.

Feed Mills:

Thorough cleaning, dehydration, grinding, blending, and pelletizing are operations performed by formula feed mills which give rise to particulate emissions. It is estimated that these emissions total 18 pounds per ton of feed produced. It was again assumed that a single fabric filter system would be provided to treat the combined gas volume from these operations.

The gas volume requirement was estimated to be 1.38 ACFM per hundred weight (cwt) production per day. The fabric filter cost factors applied were the same as those used for grain elevators.

The 1967 Census of Manufactures estimates that the production of formula feed was 49 million tons in that year. It was assumed that capacity in the industry is twice the production rate.

Using these assumptions and an estimated growth in capacity of 3.5 percent per year, a required 1977 investment of $19.4 million was calculated with an annual cost of $4 million in that year.

TABLE 4-28.

CAPACITY DISTRIBUTION AND CONTROL COSTS FOR COUNTRY ELEVATORS, 1967

Capacity Range (1000 bu)	No. of Elevators	Average Production Rate (bu/hr)	Gas Volume (ACFM)	Installed Cost	Operating & Maintenance	Depreciation & Interest	Total Annual Cost
0-25	291	10	660	$ 1,320	$ 80	$ 200	$ 280
25-75	1108	40	2,640	5,280	320	790	1,110
75-150	1691	90	5,280	10,560	630	1,580	2,210
150-250	1815	180	10,560	21,120	1,270	3,170	4,440
250-500	2096	330	19,800	39,600	2,380	5,940	8,320
500-1,000	1002	640	38,280	76,560	4,590	11,480	16,070

TABLE 4-29.

CAPACITY DISTRIBUTION AND CONTROL COSTS FOR TERMINAL ELEVATORS, 1967

Capacity Range (1000 bu)	No. of Elevators	Average Production Rate (bu/hr)	Gas Volume (ACFM)	Installed Cost	Operating & Maintenance	Depreciation & Interest	Total Annual Cost
750-1,000	251	160	14,310	$ 28,620	$ 1,720	$ 4,290	$ 6,010
1,000-2,500	634	330	29,520	59,040	3,540	8,860	12,400
2,500-5,000	177	660	59,040	118,080	7,080	17,710	24,790
5,000-10,000	73	1410	126,540	253,080	15,180	37,960	53,140
>10,000	35	2810	253,080	506,160	30,370	75,920	106,290

3. Industry Structure

a. Characteristics of the Firms

Country elevators of commercial importance numbered 8,003 in 1967. Although scattered throughout 48 of the 50 States, these were concentrated in the major grain-producing areas. The capacities ranged from 10,000 to 1 million bushels with an average of approximately 260,000 bushels. Approximately 2,000 small facilities (capacities of less than 5,000 bushels, or equivalent to storage found on many farms) were not included.

Ownership of country elevators can be cooperative, independent, or line. Cooperative ownerships are established by laws and controlled by farmer associations. Independent elevators are owned by individual merchants. Line ownerships are chains of elevators owned by large handling or processing firms. For 1967, 4,853 country elevators (61 percent of the total) were controlled by 2,579 cooperative associations. A majority of the remaining 3,150 elevators were independently owned; a small number were line elevators controlled from a central office.

Terminal elevators numbered 1,170 in 1967. Ownership is difficult to trace, but it is expected that control belongs to some 600 companies, chiefly the large grain merchandisers, processors, and firms oriented toward the export market. The capacity range for terminals in 1967 was 1 to 18 million bushels with an average storage capacity of over 2.5 million bushels.

b. Operating Characteristics

Total country elevator storage capacity was estimated at 2.10 billion bushels in 1967. The amount of grain and soybeans sold from farms amounted to 6.06 billion bushels; approximately 83 percent of wheat and feed grains sold off farms went directly to country elevators--5.03 billion bushels. With capacity at 2.10 billion bushels, the average industry turnover rate was 2.4 times. Terminal capacity was approximately 3.01 billion bushels, grain throughput 5.15 billion bushels, and turnover rate of 1.7.

In many areas the country elevator derives a large part of its revenue from sideline businesses and customer services. Considerable revenue is also received from Government price-support programs since virtually all elevators are registered under the Uniform Grain Storage Agreement and are eligible to store Government-owned grains and oilseeds. Several surveys conclude that gross income from marketing grain make up only 25 percent of total gross income from all sources.

4. Market

Depending upon location, country elevators sell grain to terminals, to exporters, and/or to processors. If there is a choice of more than one market, it is necessary for the operator to have contacts in several directions, although often one cash-grain commission merchant keeps him informed on alternative outlets. This gives the elevator operator advantages in buying, for he can pay prices in accordance with the best outlet and attract more grain to his elevator.

Competition between elevators can be classified as moderate. In grain-producing areas there are normally several elevators within a county and most farmers are within easy transportation distance of two or more elevators. Nevertheless, there are product, service, and location attributes which can insulate a country elevator from the competition of others. Empirical studies have found that most farmers do not show the propensity to shop around for better prices. Competition, then, is partly on service and partly on price, with customer loyalty providing a certain moderation.

5. Trends

Although erratic, national output of food grains has been growing at an approximate rate of 3.5 percent per year. It is expected that grains handled by country and terminal operators have and will continue to follow this same pattern.

The number of elevators decreased through the forties and fifties; then construction began to increase and the number of facilities increased at a relatively slow rate of 2 percent per year during the sixties. Many elevators are still relatively old, but it is expected that they will be replaced by modern units more rapidly than in the past. Many recent country elevator additions have been large (storage capacities of 200 to 500 thousand bushels), and there is some concern that excess capacity may become a major problem.

Profits have been historically low. Inefficient operations, poor hedging policies, underutilization of facilities, and erratic changes in the futures market can cause losses. A survey of the operating results of some 50 cooperative elevators during the period 1965-67 showed an average net savings at 3.5 percent of sales. Profit levels for the next 5 years are expected to remain at the same level.

6. Economic Impact of Control Costs

a. Impact on a Plant

Operating statements for three model elevators--A, B, and C--were constructed. Table 4-30 shows the first two plants (A and B) with rated storage capacity at 100,000 and 260,000 bushels, as representatives of small and medium-large country elevators, and the third model as representative of a typical terminal operator. The operating statements for the three models are based on six assumptions: (1) The turnover rate for Models A and B (country elevators) equals 2.4 times storage capacity; (2) Country elevator volume is 58 percent wheat and 42 percent

TABLE 4-30. MODEL ELEVATOR DESCRIPTION

Characteristic	Elevators		
	Model A	Model B	Model C
Capacity (Bushels)	100,000	260,000	2,500,000
Grain Throughput (Bushels)	240,000	624,000	4,250,000
Plant Investment Cost	$120,000	$300,000	$3,000,000
Control Investment Cost	$ 10,560	$ 27,456	$ 264,000

corn--wheat is bought at $1.39 per bushel and sold at $1.50; corn is bought at $1.05 per bushel and sold at $1.16 and both buy prices were estimated at average nationwide levels received by farmers in 1967, with the cash basis profit at 11 cents per bushel; (3) Operating costs, fixed and variable, were estimated at 8.8, 6.0, and 4.0 cents per bushel for Models A, B, and C, respectively; (4) The turnover rate for Model C (terminal elevator) is 1.7 times storage capacity; (5) Terminal volume is entirely in wheat, purchased at $1.50 per bushel and sold at $1.59 for a cash basis profit of 9 cents per bushel; and (6) Results of the statements are in terms of savings--that is, income before taxes. Many elevators are cooperatively owned and savings are normally refunded to patrons. Results of the operating statements, based on these assumptions, are shown in Table 4-31.

b. Impact on the Firms

Most country elevators have interests in marketing a wide variety of farm supplies. Grain handling often amounts to only 25 percent of terminal volume. Most country elevators, however, are relatively small companies operating at very low profit margins. If the burden of control is not passed on in the form of price increases, it would normally lower grain-handling income by some 20 to 40 percent, and in the worst situations, could compound existing losses from precontrol operations. Terminal elevators, because of their larger sizes, financial strengths, and/or captive ties to major processors, should feel less impact.

TABLE 4-31. MODEL INCOME STATEMENTS

Item	Elevators Model A (Dollars)	 Model B (Dollars)	 Model C (Dollars)
Sales	326,000	847,600	6,757,500
Grain Purchase Cost	299,600	778,960	6,375,000
Operating Cost	21,120	37,400	170,000
Annualized Control Cost	2,218	5,767	55,450
Savings Before Control	5,280	31,200	212,500
Per Bushel	0.022	0.050	0.050
Savings After Control	3,062	25,433	157,050
Per Bushel	0.0128	0.0408	0.037
Control Cost Per Bushel	0.0092	0.0092	0.013

c. Demand Elasticity and Cost Shifting

Country and terminal elevators have historically been an integral part of the Nation's grain distribution system. As such, demand for their handling and storage services would be inelastic with regard to price. It is expected that elevator owners should be able to shift most of the control cost on to consumers. This conclusion is supported by several considerations: (1) All elevators have been or will be affected by pollution control, and costs per bushel are reasonably constant for most elevators (approximately 1.0 cent per bushel handled); (2) The industry in general would not be able to tolerate the relatively severe effect on earnings; and (3) Competition is considered moderate, with many elevators isolated from competitive pressure.

There is some question about whether costs would pass upward to grain consumers or downward to the farmer. Historically, cost increases in the grain distribution system have been passed forward, as in the case of increased transportation expenses, and farmers have been partly protected by Government price support programs. Some 60 percent of all country elevators are farmer-controlled cooperatives. Thus, it is expected that costs will be passed on to the consumer.

With respect to international grain trading, the effect of price increases on American exports must be viewed relative to the policies of the U.S. Government. Because the current level of domestic grain prices would necessitate a selling price well above that which could be offered by other competitive exporting countries, the Federal Government has instituted two general types of programs to encourage commercial exports: (1) The first involves sales by the Government from grain stocks acquired under the domestic price support program; such sales are made to private exporters at levels below the domestic market price; (2) The second involves direct financial assistance in the form of export payments. In general, then, the export market is being subsidized, and the Government would be expected to assume the price increase due to air pollution control. Based on the 1967 export volume of grains, such costs should amount to approximately $17 million. Relative to the current level of Federal support for grain export programs, this additional burden is minimal.

d. Effect on Industry

Many elevators are old and inefficient from a profit and volume point of view and may be replaced if faced with control costs. Replacements will probably be larger units, which may cause some excess capacity pressures.

On the other hand, several industry journals[1/] have indicated that air pollution control may increase operating efficiencies in the long run. Compliance with standards can help reduce the dangers of explosion and thereby reduce insurance premiums, can lower grain wastage, can reduce maintenance and cleanup costs, can improve rodent control, and can improve work force efficiency through better plant environment.

[1/] See References 4,5, and 6 at end of this subsection.

REFERENCES FOR SUBSECTION E

1. The Cargill Corporation, private communication.

2. National Air Pollution Control Administration, "Air Pollutant Emission Factors", 1970.

3. United States Department of Commerce, "Census of Manufactures", 1967.

4. Anderson, Thomas H., "How We Are Meeting the Challenge of Air Pollution", Feeds Illustrated, pp. 12-14, August 1967.

5. "Clean Air Is Profitable", Feeds Illustrated, pp. 15-16, August 1967.

6. "Prevention of Dust Explosion in Terminal Grain Elevators", National Board of Fire Underwriters, Pamphlets 61 Band 61C, New York.

F. Iron Foundries

1. Introduction

a. Nature of Product and Processes

Iron foundries produce castings, such as machine and automobile parts, from gray iron, pig, and scrap. The industry utilizes four types of furnaces to melt iron for casting--electric arc, electric induction, reverberatory, and cupola furnaces. Cupolas currently account for over 85 percent of all castings, with electric arc and induction accounting for most of the remainder. Electric induction and reverberatory furnaces emit relatively small quantities of pollutants and thus require little or no air pollution control expenditures. Since electric arc furnaces account for less than 5 percent of industry production, an analysis of their control costs is not presented.

The report focuses on control of pollutants from cupola furnaces. Cupolas are vertical, cylindrical furnaces in which the heat for melting is provided by burning coke in direct contact with the metal charge. Most foundry emissions emanate from this metal-melting operation.

b. Emissions and Costs of Controls

Particulates, in the form of dust and smoke, and carbon monoxide are the significant emissions from cupolas. Particulates arise from fines in the coke and flux charge, from metal fuming, and from dirt and grease introduced with scrap.

In 1967, foundries with cupolas emitted 217 thousand tons of particulates and 3,200 thousand tons of carbon monoxide. With industry growth, these emissions would increase to about 260 and 3,800 thousand tons respectively in FY 1977. Implementation of controls would reduce them to 30 thousand tons of particulates and 230 thousand tons of carbon monoxide in FY 1977.

Carbon monoxide emissions can be reduced by the use of afterburners which oxidize them to carbon dioxide. Afterburners in combination with gas-cleaning equipment, such as wet scrubbers or fabric filters, can achieve compliance with stringent process weight regulations for particulates and a 95 percent removal rate for carbon monoxide. The regulations selected for this report would require the industry to increase its present average removal efficiency of 12 percent for particulates to 90 percent and control of carbon monoxide, from 18 to 95 percent.

Of the control equipment capable of particulate removals at or above the 90 percent level, only high-energy wet scrubbers have been used on cupolas without difficulty. Several foundries, especially in the Los Angeles area, are using fabric filter baghouses with some degree of success. Successful operation of fabric filter systems requires afterburners, gas-cooling equipment, high-temperature filtration material, and decreased filtration velocities. Maintenance costs are high, and the costs of using them are greater than for wet scrubbers except in the case of very small cupolas.

The total investment required to meet the proposed standards by FY 1977 using wet scrubbers, would be $348 million. The corresponding annual cost would be $126 million.

c. Scope and Limitations of Analysis

This report is limited to control of the melting operations because nonmelting operations within foundries are consistently controlled with high efficiency equipment.

The analysis of economic impact is limited to independent jobbing foundries, since the financial structure of captive foundries is indistinguishable in publicly available data from that of their parent company. Impact on a captive foundry cannot therefore be determined and its control costs are passed on to purchasers through the final product(s) of the parent company.

2. Engineering Basis of Analysis

The emission rates for type of melting furnaces and various control applications are shown in Table 4-32.

Nationally, the overall control levels for particulates and carbon monoxide are 12 and 18 percent, respectively, based on a comprehensive questionnaire survey conducted jointly by the National Air Pollution Control Administration and the Department of Commerce in 1968.

Cost equations have been developed (National Air Pollution Control Publication No. AP-74) relating investment and annual costs to melting rates. Annual depreciation charges from this report were adjusted to reflect an equipment life of nine years for both fabric filters and wet scrubbers. Control costs have been developed for each of ten model plants to represent the broad range of cupola size and operational practice within the industry. For each plant size, the control system was chosen to meet both process weight and opacity regulations. Only high energy scrubbers and fabric filters can meet these regulations.

The survey data and least cost solutions, based on Publication No. AP-74 (joint NAPCA-Department of Commerce survey), suggest that high energy wet scrubbers are ideal for cupolas the size of 14 tons per hour or greater melting capacity. Fabric filters are the choice for smaller cupolas. Fabric filters are also suggested for electric arc furnaces. Costs were developed based on this rationale. Included in these costs are requirements for afterburner control to destroy carbon monoxide. Table 4-33 shows unit and total cost for the ten plant sizes in industry, for both investment and annual expenditures.

TABLE 4-32. EMISSION FACTORS FOR GRAY IRON FOUNDRIES

Type of Furnace	Particulates, lb/ton metal charged	Carbon Monoxide, lb/ton metal charged
Cupola		
Uncontrolled	17.0	145
Wet Cap	8.0	---
Impingement Scrubber	5.0	---
High-Energy Scrubbers	0.8	---
Electrostatic Precipitator	0.6	---
Baghouse	0.2	---
Electric Arc Furnace	7.5	---
Reverberatory	2.0	---
Electric Induction	1.5	---

SOURCE: Environmental Protection Agency

TABLE 4-33. CUPOLA EMISSION CONTROL COSTS

Melt Rate (tons/hr)	Number of Controls	Unit Investment $	Total Investment $	Unit Annual $	Total Annual $
1-4	80	52	4160	18	1440
5-6	80	92	7360	32	2560
7-8	140	132	18480	46	6440
9-14	420	212	89040	73	30660
15-17	120	262	31440	95	11400
18-21	140	303	42420	111	15540
22-26	100	378	37800	136	13600
27-30	40	447	17880	162	6480
31-40	60	515	30900	185	11100
>40	16	721	11536	248	3968
	1200		291016		103188

3. Industry Structure

a. Characteristics of the Firms

The iron foundry industry consisted of approximately 1,730 plants in 1967 with 2,250 cupolas. The total national capacity for the industry was 17 million tons of castings per year. Production was 14.3 million tons per year with a value of shipments of $2.7 billion.

Although there are many small establishments in the industry, production is dominated by a few large firms. The four largest companies accounted for approximately 27 percent of the industry's value of shipments in 1967, and the eight largest accounted for 37 percent.

Many of the largest firms are "production foundries", which have the capability of economical production of large lots of closely related castings. Most of their output is captive (owned and controlled by other businesses); in fact, almost half of all iron comes from captive plants which do not generally produce for the highly competitive open market.

Iron foundries range from primitive, unmechanized hand operations to heavily equipped plants in which operators are assisted by electrical, mechanical, and hydraulic equipment. Captive plants are more likely to be mechanized and better equipped with emission control equipment than are noncaptive plants.

The nature of the iron foundry industry is such that foundries can be found in almost all urban areas. The economies of scale for the industry do not prohibit the continued existence of relatively small foundries. Since many foundries are operated in conjunction with steelmaking facilities, they are concentrated in the "steel States": Pennsylvania, Ohio, Michigan, Illinois, and Alabama.

4. Market

a. Competition Among Sellers

The iron foundry industry is characterized by intense price competition among the many small jobbing foundries which has spurred a drive for lower operating costs and productivity gains. Other areas of increasing competition are casting quality along with engineering design services available to the customers. Unforunately, many (smaller) foundries have had capital only for additions to capacity; investments in cost-saving and quality improvement facilities have been bypassed or postponed. Larger foundries also have competitive advantages in that they usually can offer the services of better sales and engineering staffs, are more mechanized, and have more sophisticated quality control equipment.

The net effect of these conditions is that many small foundries that cannot cope with increasing needs for capital, demands for better quality and service, and rising labor costs are being forced out of business, but the larger, more stable firms are increasing their capacities in order to reduce unit costs and absorb the additional demand. Also, an increasing number of large purchasers of castings are establishing captive foundries in order to gain a ready supply of quality castings; however, since these additions to capacity have been unable to keep pace with the expansion of demand and the loss of capacity caused by closed foundries, users are finding it increasingly difficult to obtain an adequate supply of specialty iron castings.

b. Customer Industries

The major customers of the iron foundry industry are also major constituents of the national economy. The health of the industry is therefore closely related to the health of the gross national product (GNP). The major markets for foundry castings include motor vehicles, farm machinery, and industries that build equipment for the construction, mining, oil, metalworking, railroad, and general industry markets; these industries are considerably larger and more powerful than the iron foundry industry. Each customer firm has many times more assets than the foundries from which it buys. With financial strength and generally greater management expertise, such firms can play many small foundries against each other to maintain severe price competition even under conditions of high demand for castings.

c. Foreign Competition

Direct imports of castings as well as castings in imported machine tools, autos, textile machinery, and diesel engine parts do enter the American market. However, Department of Commerce statistics indicated a volume of only $2.25 million for direct imports in 1967. This is estimated by the industry as approximately one-quarter of the actual total. Even if a total import volume of $9 million is assumed, imported castings and component castings would have been equivalent to less than one percent of the $2.7 billion total value of shipments in 1967. Imports, therefore, do not constitute a major threat to the American iron-casting market. The high cost-per-ton of shipping compared to the relatively low cost-per-ton of production is probably the most significant barrier to imports.

5. Trends

The number of iron foundries in the United States has declined from about 3,200 in 1947 to 1,670 in 1968, with a trend of reducing by about 70 installations per year. From 1967 to 1969, the net decrease slowed to 42 annually. In accordance with the historic trend, the number of iron foundries is projected to be approximately 1,100 by 1980; in addition, the average size of iron foundries has been increasing steadily, with average annual production per foundry increasing from 3,800 tons in 1947 to 9,700 tons in 1969, and by 1980 the average annual production per iron foundry is projected to be approximately 16,500 tons.

The tonnage of malleable iron castings is expected to remain relatively constant. Ductile iron tonnage has increased every year and is expected to double the 1969 tonnage by 1980. Total production of iron castings, excluding ingot molds made directly from blast furnace iron, has been projected to about 17 million tons per year by 1980, an average growth rate of 2 percent per year.

From 1958 to 1967, the average price of gray iron castings rose steadily at the rate of 2 percent per year. At the same time, the prices of the two major raw materials--pig iron and scrap iron--have fallen at an annual rate of 2.3 percent. However, while material costs have declined, labor costs have advanced more rapidly than the prices of castings and have kept a continued upward pressure on prices.

6. Economic Impact of Control Costs

a. Impact on Plants

Model plants have been developed in a separate study[2] to demonstrate the impact on foundries if control costs cannot be passed on in higher prices. The results of this analysis are presented in Table 4-34.

TABLE 4-34. MODEL PLANT FINANCIAL ANALYSIS

Operating Characteristics	Size Range by Value of Shipments ($ million)				
	.5	.5-1	1-2.5	2.5-10	10
Melt Rate (tons/hr)	4	6	8	12	20
No. of Cupolas	1	1	1	2	2
Production (ton/yr)	1,050	3,000	6,300	12,900	40,000
Control Cost ($/ton)	14.60	9.50	6.50	4.90	2.60
Control Cost (% Sales)	2.9	3.2	2.8	1.6	.7
Reduction in Income (%)	59	49	41	23	11
Control Investment (% Net Investment)	19	30	26	12	5

Air pollution control costs would increase the value of shipments for large foundries by about 0.7 percent, and for small single-cupola foundries, as much as 3.2 percent. To small foundries, control costs represent an income reduction of about 60 percent, while margins for larger firms would be reduced by only 11 percent if costs could not be passed on to customers. Investment in control equipment would equal approximately five percent of the value of capital for the largest firms and as much as 30 percent for small firms.

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[2] "Economic Impact of Air Pollution Controls on Gray Iron Foundry Industry". National Air Pollution Control Administration publication AP-74.

While large foundries will be affected less severely by pollution control costs than will small foundries, the industry generally can little afford a reduction in profit rate, since its 6.8 percent return on investment is already below the overall manufacturing average of 8.1 percent.

Because the investment in control equipment is large compared to the book value and profitability of many foundries, a serious problem is how to finance the investment. This applies particularly to the small independent jobbing foundry which cannot generate sufficient capital internally. The foundry industry generally is not an attractive investment in stock or bond markets due to its low rate of return and its slow profit growth. Neither is it a good risk for commercial banks due to the high ratio of control investment to book value and the low cash flows of many small foundries. The Small Business Administration (SBA) is currently the only source of funds available to many foundries; it prefers to guarantee loans made by banks, but it will loan funds directly in some cases, but not for firms with insufficient cash flows.

b. Demand Elasticity and Cost Shifting

The economic impact of pollution control costs varies with the industry's ability to pass cost on to the consumer in higher prices. This ability is largely dependent on elasticity of demand for the product--the degree to which the volume of sales declines in response to price increases. Demand for castings is relatively inelastic--in that demand will not decline appreciably with increases in price--because most castings are inputs for the production of more complex final products and thus constitute a small portion of the cost of the final product. However, possible substitute products, (e.g., aluminum, steel, and other metals) are somewhat more costly than iron castings and are usually subject to similar upward price pressures such as rising labor and pollution control costs. Thus, a small price increase due to pollution control will have little effect on the market for gray iron.

c. Impact on the Industry

Despite inelastic demand, sharp competition among the many jobbing foundries will make price adjustments difficult for those that experience higher than average control costs. Large mechanized firms will incur lower control costs than will smaller or older foundries. To the extent that they compete for the same market sectors, the lower-cost foundries will establish price levels that prevent the less efficient firms from raising prices sufficiently to fully cover their control costs. The average price of castings is expected to increase by about 2.7 percent in response to stringent air pollution control regulations; such a price increase would leave approximately one-fourth of the firms in the industry with reduced profit margins, and many of these firms would be forced into marginal or submarginal financial positions.

The nonuniformity of control costs, along with the lack of investment capital, will force most foundries to postpone implementation of control for as long as possible. Many small foundries, faced with reduced profit margins and an inability to raise investment capital, will be forced to merge or to go out of business. Some remaining firms will continue to operate at reduced profit rates. However, the large, more stable foundries will increase capacities to meet expanding demand, will improve efficiency, and will continue to operate profitably. In effect, the costs of pollution control will accelerate the trend toward fewer and larger foundries. It is apparent that the iron foundry industry will be among those industries most severely affected by air pollution control.

REFERENCES FOR SUBSECTION F

1. "Systems Analysis of Emissions Control by the Iron Foundry Industry", by A. T. Kearney, CPA 22-69-106, Air Pollution Control Office, Environmental Protection Agency, February 1971.

2. "Economic Impact of Air Pollution Controls on the Gray Iron Foundry Industry", Publication No. AP-74, National Air Pollution Control Administration, U. S. Department of Health, Education, and Welfare, November 1970.

G. Iron and Steel

1. Introduction

The iron and steel industry consists of hundreds of firms engaged in one or more of the processes involved in transforming iron ore into fabricated steel products. These processes include: coking, in which coal is reduced to coke in coke ovens; sintering, in which iron ore is beneficiated and prepared for charging into blast furnaces; smelting, in which pig iron is produced from iron ore, coke, and limestone in blast furnaces; refining, in which iron ore is refined into steel (and alloyed if desired) in open hearth, basic oxygen, or electric furnaces; rolling, in which raw steel is shaped into blooms, billets, slabs, and other basic shapes; finishing, in which basic shapes are rolled, drawn, coated, or otherwise treated to produce sheet, strip, tin plate, pipe, wire, and other products for use in manufacturing; and fabrication of finished products. Blast furnaces are always well controlled to prevent the emissions of particulates, while the gaseous emissions are fully utilized in the production of process heat. At present, very little is known about the emissions or present control patterns for the scarfing machines that are used to clean the surface of billets before rolling. Control of coking operations at existing facilities, which constitute significant sources of both particulate and gaseous emissions, does not appear to be either technologically or economically feasible before FY 1977. There does not appear to be adequate technology to significantly reduce particulate emissions during coal charging and coke pushing operations from byproduct coking. Required technology consists of sealed ovens and offgas collection of particulates vented to scrubbers, such as are installed on modern coke ovens. However, most older ovens are not structurally designed for this approach. Therefore, total replacement of many coking plants would be required. The steel industry expects technological developments in a few years to improve the coking process itself ("third generation" technology) which will require large amounts of new capital. This is a deterrent to investing heavily in modern facilities which will become obsolete within a few years. Cost estimates of $1 to $1.5 billion for control of current facilities have been mentioned by various sources, but these estimates are of questionable reliability. For these reasons, control cost and emission estimates for coking have not been included in this report.

This report focuses on the emissions and air pollution control costs of the sintering and steelmaking operations.

2. Engineering Basis of the Analysis

This analysis was limited to control of particulate emissions from open hearth, basic oxygen, and electric arc furnaces and from sintering operations. Potential emissions of other pollutants are normally controlled to acceptable levels. The uncontrolled rates of particulate emissions are presented by process in Table 4-35.

TABLE 4-35. UNCONTROLLED PARTICULATE EMISSION RATES

Process	Emission Rate (lb/ton produced)
Open hearth (nonoxygen lanced)	12
Open hearth (oxygen lanced)	22
Basic oxygen	46
Electric furnace	11
Sintering (windbox)	20
Sintering (discharge)	22

In estimating present emission levels it is necessary to adjust the uncontrolled emission rates to allow for controls already in use. Detailed information on these is not readily available. On the basis of limited data[1,2,3] estimates of controls in place in 1967 were made and are given in Table 4-36. It was assumed that open hearth furnaces are controlled only where oxygen lancing is used.

TABLE 4-36. PARTICULATE CONTROL LEVELS (1967)

Process	Controlled Production (percent)	Average Control Efficiency (percent)
Open hearth furnace	27	90
Basic oxygen furnace	100	95
Electric furnace	61	90
Sintering (windbox)	90	75
Sintering (discharge)	0	--

Required particulate removal efficiencies for each process were calculated as a function of process size, based on the emission standards shown in Appendix I. These are shown in Table 4-36.

All types of furnaces and sintering machines were assumed to require additional control. Costs were calculated on the basis of using high energy wet scrubbers for 50 percent of open hearth and basic oxygen furnaces and electrostatic precipitators for the other 50 percent of these furnaces; fabric filters were assumed for electric arc furnaces, and medium energy wet scrubbers for sintering machine windboxes and discharges. The cost estimating parameters are shown in Table 4-37.

The cost relationship for electric arc furnaces was calculated on the assumption that two furnaces exhaust into a single control system with appropriate staggering of operations. If possible, two furnaces of equal capacity were paired; if not, furnaces with no more than a 25 percent difference were paired. When two furnaces of different capacities were controlled, the larger capacity was assumed. Control costs for single furnaces were calculated by dividing the control cost for two furnaces (each of which has a capacity equal to the single furnace) by 1.4 to allow for a reduced ducting and blower requirement as well as reduced average load.

TABLE 4-37. COST ESTIMATING PARAMETERS*

Unit Operation	Control Equipment	Units of Capacity	Cost Estimating Parameters* "a" Investment	Annual	"b" Investment	Annual
Open hearth Furnace	high energy venturi scrubber electrostatic precipitator	tons/melt	8,308	6,576	0.7	0.7
Basic oxygen furnace	high energy venturi scrubber electrostatic precipitator	tons/melt	35,775	16,318	0.7	0.8
Electric arc furnace	fabric filter	tons/melt	12,902	8,400	0.7	0.7
Sintering (windbox)	medium energy venturi scrubber	tons of sinter/day	837	518	0.8	0.7
Sintering (discharge)	medium energy venturi scrubber	tons of sinter/day	15,835	5,541	0.3	0.3

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* The cost function is $y = ax^b$, where y = control cost, x = capacity, and "a" and "b" are cost parameters that depend on the type of process. The same function was applied to the calculation of both annual and investment costs by simply using the appropriate a's and b's. To illustrate the use of the parameters, suppose that it is required to determine the investment and annual cost of controlling a basic oxygen furnace with a capacity of 400 tons per melt. The investment cost (y) is therefore $\$35,775\ (400)^{0.7} = \$2.36$ million with an annual cost(y) = $\$16,318\ (400)^{0.8} = \$1.96$ million.

3. Emissions and Costs of Control

This analysis deals only with emissions and controls for particulates from sintering and furnace operations. Carbon monoxide is essentially completely controlled in blast furnaces by process air preheating and in basic oxygen furnaces by flaring. Because sintering is gradually being replaced by the pelletizing process in the industry, it declined more than 10 percent over the last 3 years even though production of pig iron increased by slightly more than 10 percent. This trend will lower potential emissions over the next 5 years and reduce the required investment and annual costs correspondingly. Neither emissions nor control costs for pelletizing have not been included in this analysis, nor have the costs been added, due to the lack of some of the data essential to these calculations.

Based upon the best available data, the average level of particulate control in 1967 is thought to have been about 55 percent for sintering and steelmaking operations. To comply with the Clean Air Act by FY 1977, an average level of particulate control of 98 percent will be required to reduce particulate emissions from a potential of 1,991 thousand tons in FY 1977, with the same controls as in 1967, to 89,000 tons, with the 98 percent control and the decline in sintering.

To implement the required increases in air pollution control levels by FY 1977, it estimated that an investment of $841 million will be required, and that total annual cost will be $306 million.

4. Scope and Limitations of Analysis

This analysis focuses on integrated basic steel firms which produce nearly all the raw steel made and account for more than 90 percent of steel output. Air pollution emissions that exceed the standards assumed for this study are produced primarily by the sintering plants and open hearth or basic oxygen furnaces of basic steel producers. Electric furnaces are also emission sources to a lesser extent. However, when used by secondary steel producers making specialty high alloy steels, electric furnaces are normally controlled to a high level of efficiency to avoid loss of valuable alloying metals and, therefore, are not generally faced with additional control costs.

Data on the operations of the steel industry are more available than for most industries. Nevertheless, the steel market is complicated by the vast variety of distinct products and the variations in product mix from one company to another, so comparison of the impacts of changes in the cost of producing raw steel, as they affect different companies is difficult. Detailed data are not available on such aspects of financial management as depreciation policy, net value of investment, pricing policy, and tax accounting; thus it is especially difficult to estimate profit potentials for these firms.

5. Industry Structure

In 1967 there were 142 steel plants in the United States with a total capacity, production, and value of shipments of 165 million tons, 127 million tons, and $13.3 billion, respectively.

There were 86 steel firms in the United States in 1967. Of these, 21 accounted for more than 90 percent of production; they included all of the largest integrated firms in the industry, with outputs ranging from just under 1 million to more than 30 million tons and with sales varying from $85 million to more than $4 billion, and with profits ranging from $172 million for one firm to a loss of nearly $7 million for another. Of the 21, the two largest firms produced 40 percent and eight produced over 75 percent of the industry output.

6. The Market

The steel industry is usually described as an oligopoly characterized by administered prices and price leadership. Typically, list prices are virtually the same for all firms and remain unaffected by minor changes in market conditions. Individual prices may be shaded through the use of special discounts or premiums, but primarily firms adjust prices to short-term market changes by varying output. When price changes do occur, they are usually initiated by one of the largest firms and all other firms quickly follow the pattern. Competition emphasizes product quality and customer service more than price.

Steel is sold to customers in every major industrial sector of the economy. The major purchasing industries, however, are motor vehicles, heavy equipment and machinery, containers, and appliances. These industries strongly follow the swings of the business cycle, and as a result cyclical changes in the national economy tend to have magnified effects on the market for finished steel. The basic position of steel in the economy also indicates the probability that the long-run trend of the domestic market for steel will be steady expansion and gradually rising prices.

The steel industry is subject to significant foreign competition. During the sixties, foreign participation in the U.S. steel market increased and posed a real threat to the market for some products, because the export market for U.S. steel did not balance imports. This competitive pressure was eased by the signing of an informal agreement in December 1968, with the Japanese Iron and Steel Exporters Association and with the Association of Steel Producers of the European Coal and Steel Community to limit exports to the United States to not more than 5 percent increases annually for 1969 through 1971.

7. Trends

Investment in new steel capacity has been heavy over the last decade and is predicted to continue at a high level, but with a slower rate of growth. The trend is away from the older open hearth furnaces in favor of more efficient basic oxygen and electric arc furnaces.

The trend of profits is difficult to determine because net income after taxes for steel firms varies substantially from year to year. Among the factors causing these fluctuations are the heavy "startup" costs for new facilities, the impact of strikes, the changes in accounting and tax practices, and the tendency of firms to change output rather than price in response to short-term market changes.

In the past several years the steel industry has experienced difficulty in maintaining a satisfactory rate of profit due to the general economic slowdown of the Nation, the strong foreign competition, and the competition from other materials. Prices have continued strongly upward, while production has been below the optimum rate of 85 percent of capacity. Both reactions to lower-than-desired overall sales indicate the oligopolistic character of the steel market.

The basic competitive pattern of the steel market is not expected to change during the seventies, although lesser changes are occurring and will persist through FY 1977. The largest firms will continue to dominate and to set price patterns. However, the pattern of price leadership by one or two firms seems to have been weakened, and more flexible prices and more open price competition may be expected.

Foreign competition is increasing and may become considerably stronger when the voluntary agreement limiting exports to the United States from Europe and Japan expires at the end of 1971. Even with this agreement, competition has been increasing, especially in the speciality steels and high profit items. Lower average profits on sales have resulted for U.S. firms and have caused some to abandon markets for particular items.

Steel faces strong competition from other metals and plastics in many uses, also. This, combined with the foreign competition, largely explains the fact that the annual growth rates projected for the industry through FY 1977 of 2.07 percent for capacity and 2.46 percent for production are lower than those used in last year's report.

8. Impact of Control Costs

The required investment and annual costs of air pollution control for each steel firm will vary depending on the number and sizes of its plants and on the types and capacities of its steelmaking furnaces. Cost estimates are calculated on the following equipment designations: high energy wet scrubbers for 50 percent of open hearth and basic oxygen furnaces, and electrostatic precipitators for 50 percent; fabric filters for electric arc furnaces; medium energy wet scrubbers for sintering machine windboxes and discharges.

Both the required investment and the annual costs for each control device vary in relation to the capacity of the furnace or machine and have been costed on the basis of data specifying individual capacities. Other than capacity, a major determinant of cost differences among plants and firms is the number of each type of furnace in use. It appears that basic oxygen furnaces, in the range of sizes most commonly used, cost substantially less to control per unit of production than open hearth or electric furnaces. Costs for basic oxygen furnaces amount to about $1.00 per ton of annual production with utilization at 85 percent of capacity. Medium-sized open hearth furnaces may require annual costs of about $1.50 per ton of annual production at 85 percent utilzation. Very large electric arc furnaces may be expected to approximately match the annual cost per ton of open hearth furnaces, but will probably be somewhat more expensive to control when a number of small electric furnaces are used.

The impact of control costs on firms may be shown by comparison of three hypothetical examples designed to show the range of costs per ton of steel production. A steel company with total annual capacity of 9 million tons and production of 6.4 million tons of finished steel per year in 1970, one-third from basic oxygen furnaces and two-thirds from open hearth furnaces, would incur estimated costs as follows: total investment, $30 million; total annual cost of $9.8 million; annual cost per ton of raw steel $1.30; and annual cost per ton of finished steel $1.53. Estimated costs for a small firm having an annual capacity of 2.24 million tons and production of 1.58 million tons of finished steel, entirely from open hearth furnaces, shows an investment requirement of $8.4 million and a total annual cost of $2.9 million, or $1.83 per ton of finished steel. Similarly, a small firm producing 1.7 million tons of finished steel in 1967 with a capacity of 2.3 million tons, using only basic oxygen and electric arc furnaces, would have an estimated investment of $7.0 million and an annual cost of $3.5 million, or $2.03 per ton of finished steel; for this firm, the high cost per ton of finished steel results from the use of 19 small electric furnaces.

Comparison of these cost estimates indicates that the impact of control costs will probably be greatest on firms using many relatively small electric arc furnaces, great for firms producing primarily with open hearth furnaces, and gradually less as the percentage of basic oxygen furnaces increases. The estimated costs are small in relation to the price of finished steel ($170 per ton in 1967), but cost differentials of the size indicated may accelerate the existing trend in the industry to retire older open hearth furnaces.

The trend of prices in the steel industry and the characteristically oligopolistic pricing pattern strongly suggest that control costs will be almost entirely reflected in price soon after they are felt by the firms. The result may be to limit sales slightly below the level that could have been obtained at lower prices. This effect would be very small. A price increase of $1.50 to $2 per ton is small relative to a selling price of $170 upward, per ton. The impact of control cost on the profitability of firms will depend largely on the general state of the economy at the time and will be significant only in a time of depressed demand for steel.

REFERENCES FOR SUBSECTION G

1. R. L. Duprey, Compilation of Air Pollution Emission Factors. Public Health Service Publication No. 999-AP-42. Durham, North Carolina: U.S. Department of Health, Education, and Welfare, National Center for Air Pollution Control, 1968.
2. " A System Analysis of Process Technology and Air Quality Technology in the Integrated Iron and Steel Industry," Preliminary Report. Batelle Memorial Institute, Columbus, Ohio, March 31, 1969.
3. Proceedings: The Third National Conference on Air Pollution (Washington, D.C. - December 12-14, 1966). Washington, D.C.: U.S. Department of Health, Education, and Welfare, (PHS), 1967.
4. Systems Analysis of the Integrated Iron and Steel Industry (Appendix C), PH22-68-65. Pittsburgh, Pennsylvania: Swindell-Dressler Company, March 31, 1969.

H. Kraft (Sulfate) Pulping

1. Introduction

a. Nature of Product and Process

The pulp industry manufactures pulp from wood and other materials for use in making paper and related products. The methods used to produce pulp from wood may be classified as chemical or mechanical; only the chemical methods cause significant air pollution problems, and two of these, the sulfite and sulfate (kraft) methods, account for approximately 75 percent of the total industry output. Sulfite pulping is a potentially serious source of sulfur dioxide when waste liquor incineration without chemical recovery is practiced. In some cases, control costs can be offset by the valuable recovery of heat and chemicals. Only kraft pulping, which accounts for approximately 64 percent of the industry output, is considered in this report.

In the kraft process, woodchips are cooked in a liquor composed of sodium hydroxide and sodium sulfide to separate the lignin from the cellulose. Pulp is produced from cellulose. The lignin is burned as a fuel in the recovery furnace. This satisfies the energy requirements for the pulping process. The chemicals recovered from the salt cake solution (black liquor) are recycled.

b. Emissions and Cost of Control

In the kraft pulping industry, three main processes emit significant quantities of particulates: recovery furnaces, lime kilns, and bark boilers. The level of sulfur dioxide emissions from the main source, the recovery furnace, generally does not exceed 500 parts per million.

The economics of the kraft pulping method depend upon reclamation of chemicals from the recovery furnace and lime kiln; hence, emissions from these processes are controlled to minimize losses of chemicals. Particulates from the bark boiler are also controlled, but controls fall short of the assumed standards in this study. Based on a total emission factor of 34 pounds of particulates per ton of air-dried pulp, the total emissions for the kraft industry were 380,000 tons for 1967. Based on a growth rate of 3.5 percent annually from 1967, the emissions in FY 1977 without the Act would be 536,000 tons. With controls adopted in this study, the level of emissions would be 80,000 tons.

By FY 1977, the kraft industry will have expended $132 million in air pollution control investments for scrubbers added to furnace facilities, lime kiln venturi scrubbers, and multitube cyclones for bark boilers; annualized costs will be $40 million.

c. Scope and Limitations of Analysis

Data sources include Government, trade, and financial publications. Analysis was aimed primarily at the entire kraft paper industry because most pulp production is captive and financial statements for independent producers of market pulp are generally not detailed enough to warrant meaningful impact analysis. Impact analysis was limited by the degree of horizontal integration in some firms within the industry and by lack of information on the type and quantity control expenditures since 1967.

Analysis of control requirements was limited to abatement of particulates emissions. Odor pollution has been recognized in this industry; however, at the present time no odor standards have been promulgated by the EPA so no realistic analysis could be made.

2. Engineering Basis of Analysis

For kraft pulping, the recovery system, which includes the furnace, smelt tanks, and lime kilns, emits significant quantities of particulates. In addition, bark boilers, which are disposal devices for bark wastes emit quantities of fly ash and perhaps some bark char. Table 4-38 shows particulates emission factors and rates for these sources.

The control of these sources was based on application of the assumed process weight standard to the recovery furnace--smelt tank as one system and the lime kiln and bark boiler as separate individual units. Normally kraft mills will recover valuable chemicals with control devices on recovery furnaces and lime kilns. Increasing the control level on these two sources will be partially compensated by values of the chemicals, which will be returned to process of liquor rejuvenation. Particulates recovered from bark boilers have no economic values.

For the purposes of analysis, it was assumed that venturi scrubbers would be added to existing recovery furnace electrostatic precipitators. All other equipment installed would be considered replacements.

The basic data for determining control requirements in pursuit of the process weight standard were taken from the three-volume study, "Control of Atmospheric Emissions in the Wood Pulping Industry", by Environmental Engineering and J. E. Sirrine. The engineering data used are stated in Table 4-39. Based on the cost curves in the same study similar to that shown in Figure 4-5, unit equipment and annual costs were developed and scaled to 1970 dollars (via use of Chemical Engineering's Plant Cost Index). The technical cost requirements for the three model plants are shown in Tables 4-40 to 4-43. Depreciable lives used in the annual costs are based on eight years for scrubbers and sixteen years for multiple cyclones.

The development of national cost requirements derived on the models was based on the mill size distribution shown in Table 4-43. Rather than perform a mill-by-mill cost calculation, estimates were determined by proportioning the model plant costs to the number of mills and average mill size representative of each model plant.

Average mill size was corrected to model plant size by scaling model plant capital related costs by use of the six-tenths rule. For example, an investment for a 300 tpd* mill would equal the investment for a 500 tpd mill raised to the 0.G. power.

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* Tons per day.

TABLE 4-38. PARTICULATE EMISSIONS FROM KRAFT PROCESSES, BASED ON 1967 CONTROL LEVEL

Source	Potential Particulates, (lbs/ton air dried pulp)	Actual Particulate Emissions, (lbs/ton air dried pulp)
Recovery Furnace	129	14
Lime Kiln	65	15
Bark Boilers	15	5
TOTAL	209	34

TABLE 4-39. ENGINEERING PARAMETERS, UNIT BASIS (AIR DRY TON PULP), FOR CONTROL REQUIREMENTS CALCULATIONS

Process Unit	Process Weight, (lbs/ton air dried pulp)	Typical Gas Volume, (ACF/ton air dried pulp)
Recovery Furnace	5400-5900	420,000
Smelt Tank	5400-5900	45,000
Lime Kiln	1100-1200	68,000
Bark Boiler	900-1000	100,000

TABLE 4-40. CONTROL REQUIREMENTS FOR A 500-TON-PER-DAY MILL

Source	Allowable Emissions, lbs. per ton air dry pulp	Control Device	Operating Efficiency (%)	Investment	Annual Cost
Recovery Furnace	1.5	Venturi Scrubbers (2)	90	$322,000	$120,000
Lime Kiln	0.8	Venturi	99	101,000	34,300
Smelt Tanks	0.1	Orifice Scrubbers (2)	97	76,000	32,800
Bark Boiler	1.0	Single-Stage Multicyclone	90	92,000	24,800
TOTAL	3.4			$591,000	$211,900

TABLE 4-41. CONTROL REQUIREMENTS FOR A 1000-TON-PER-DAY MILL

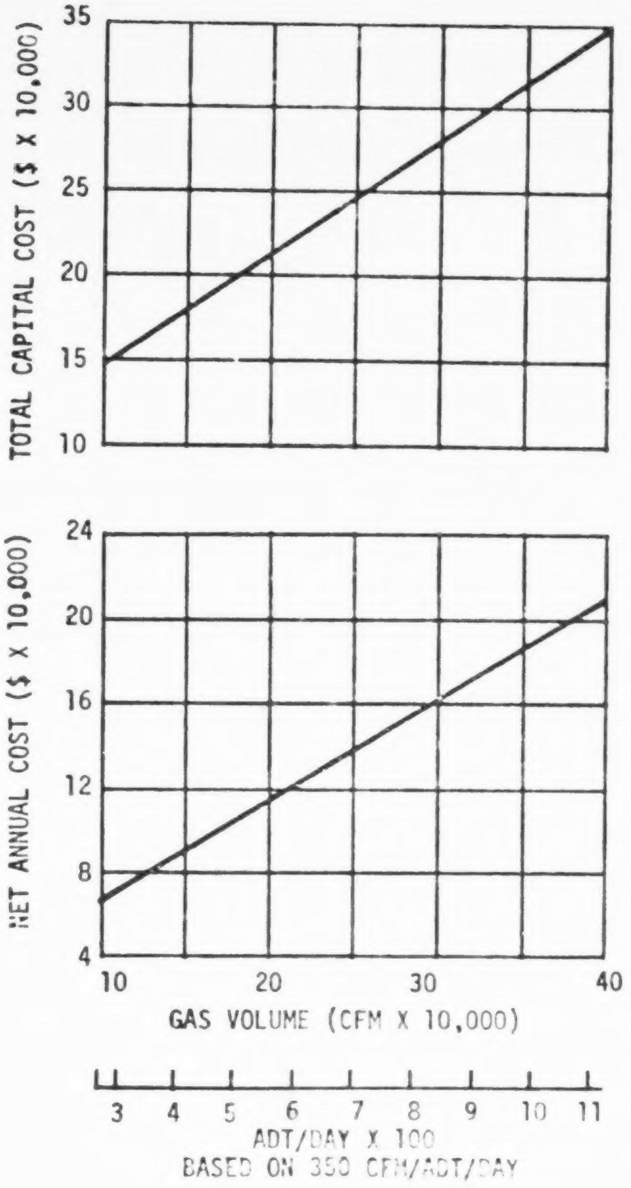
Source	Allowable Emissions, lbs. per ton air dry pulp	Control Device	Operating Efficiency (%)	Investment	Annual Cost
Recovery Furnace	0.8	Venturi Scrubbers (2)	95	$460,000	$188,700
Lime Kiln	0.6	Venturi	99	201,000	67,500
Smelt Tanks	0.1	Orifice Scrubbers (2)	97	104,000	48,600
Bark Boiler	0.7	2-Stage Multicyclone	94	253,000	67,900
TOTAL	2.2			$1,018,000	$372,700

TABLE 4-42. CONTROL REQUIREMENTS FOR A 1500-TON-PER-DAY MILL

Source	Allowable Emissions, lbs. per ton air dry pulp	Control Device	Operating Efficiency (%)	Investment	Annual Cost
Recovery Furnace	0.6	Venturi Scrubbers (3)	99	$ 621,000	$338,700
Lime Kiln	0.5	Venturi	99	247,000	81,400
Smelt Tanks	0.0	Orifice Scrubbers (3)	97	127,000	66,000
Bark Boiler	0.6	2-Stage Multi-cyclone	94	299,000	90,300
TOTAL	1.7			$1,294,000	$576,400

TABLE 4-43. KRAFT INDUSTRY MILL DISTRIBUTION BY SIZE AND CAPACITY

Model Plant, tons per day air dry pulp	Total Daily Capacity, tons air dry pulp	Mills, Number	Average Mill Size, tons per day air dry pulp
500	11,905	38	313
1000	38,556	51	756
1500	37,812	27	1400



Source: Environmental Engineering, Inc., and J. E. Sirrine Company

Figure 4-2. Control Method Costs for a 99% Efficient Venturi Scrubber Added to an Existing 90% Efficient Precipitator - Recovery Boiler (99.8% A.O.E.)

3. Industry Structure

The kraft pulping industry is a segment of the kraft pulp and paper industry, which is part of the pulp and paper industry. Many kraft pulping firms do have papermaking facilities and some have mills and plants for producing nonkraft types of pulp and paper.

In 1967, there were 116 kraft pulp mills representing the U.S. pulping capacity of 72 firms. Over half the firms operated only one pulp mill and the seven largest firms accounted for over 40 percent of productive capacity. Despite the high degree of concentration, competition in quality, service, and price was keen, and these relationships are generally the same today.

For this report, kraft pulp mills are classified into three classes: capacity of 500, 1000, and 1500 tons of air-dried pulp per day. The classification is useful to show variations in needed air pollution control expenditures and devices. Most of today's capacity is in mills producing about 1,000 tons of air-dried pulp per day; 500-ton mills are next, followed by those with 1,500 tons. The trend in size and location has been toward the small to medium sized mills located in the southeast.

a. Operating Characteristics

The average operating rate for the production of paper grade kraft pulp for 1959 through 1969 was about 92 percent. The operating rate in 1967 was 88 percent. It rose to 92 percent again in 1968 and then to 94 percent in 1969. For 1970, it declined to 89 percent.

The relation of operating rate to price, and thus to profits, is clouded. Prices exist only for market pulp and 92 percent of kraft pulp production is captive. However, higher prices for market kraft pulp appeared usually the same year or the year after an operating rate that was between 88 and 92 percent.

b. Resources

Kraft mills are located primarily in the northwest and the southeast near the raw materials of wood and water. For wood, the quality of trees and the length of growing time are important.

The typical firm has its own forest reserves, thereby controlling this portion of materials' cost and in some instances exploiting it. However, the cost of labor and required chemicals are not entirely within the industry's control. Attempts to offset the increases in them have been seen in product price rises and in adoption of techniques, such as computerized controls, which increase operating efficiency.

4. Market

Most kraft pulp production is captive. The eight percent that is marketed comes from firms without papermaking facilities and from integrated firms producing surplus for market.

Kraft pulp is produced in three forms: bleached, semibleached, and unbleached. Unbleached pulp finds uses in wrapping and bag paper, shipping sacks, and linerboard; semibleached in printing papers; bleached in sanitary food board.

Competitive products include plastic containers and wrappings, glass containers, aluminum foil, and in some instances recycled paper. The kraft industry should maintain its share in most markets. Fewest problems are expected in sanitary food board markets where virgin paper is required. Continued stiff competition, first realized in the sixties, is expected to continue in the folding carton market.

Demand for kraft pulp is derived from the demand for kraft paper and paper products which are related positively to the demand for consumer nondurables. While demand for some kraft paper products which are necessities is better explained by such indicators as population, demand for other kraft products follows more closely the indicators of economic activity such as unemployment rate and real disposable income.

Foreign trade exists in the kraft paper and products as well as the kraft pulp markets. The United States is and should continue to be the major exporter of kraft paper and board used for packaging; this is explained not only by raising economic activity trends abroad but also by the lack of adequate forest reserves in some nations. The United States is, however, a net importer of newsprint, most of which comes from Canada, and a net importer of market sulfate pulp, even though the United States exports about 40 percent of its market pulp. Market sulfate pulp imports provide about 7 percent of this country's sulfate pulp requirements. The market sulfate pulp exports are explained primarily by the increased level of economic activity and the limited quantity and inferior quality of forest reserves in the importing nations. Sulfate pulp imports into the United States, 98 percent of which come from Canada, are explained mainly by the substantial investments that some American firms have in Canadian pulp mills.

5. Capacity, Production, Prices, Sales, Profits, Trends

In the past, the industry has been characterized by the investment-price cycle. After heavily investing in new facilities to meet actual and anticipated growth in demand, the industry was faced with overcapacity. Firms tried to run plants at least at break-even levels, but prices declined especially as firms continually tried to produce at economic production levels and thus added to the over-supply problem. As a result of the lower prices, profits declined and the investment was cut back. With demand increasing fairly steadily, the relationship between supply and demand tightened, prices increased, profits rose, and new investment was undertaken.

Although the industry appeared to be in the rising-price phase of the cycle in 1969 and 1970, recent capital outlays have not expanded production capacities as they did in past cycles. Capital outlays were made in cost reducing processes of production and distribution, along with outlays for product diversification and pollution control facilities. This has reduced the growth in supply. In the face of a steadily growing demand, this will maintain a closer relationship between supply and demand, and should reduce the cyclic variations in prices and profits.

Product diversification has been instigated by the realization that land and forest reserves could be another source of revenue. Firms have entered the recreation, real estate, and lumber markets. On the other hand, pulp and paper products hold promise for those outside because firms in the lumber and plywood industries, along with some producing competing container products, have diversified into pulp and paper products.

6. Economic Impact of Control Costs

a. Impact on Plants

To determine the control costs and financial impact for the kraft industry, model plants were derived for mills of 500, 1,000, and 1,500 tons per day. The assumptions for the model plants include the number of process units shown in Table 4-44.

TABLE 4-44. MODEL PLANT PROCESS UNITS

Process Units	Model Plant Size (Tons Air-Dried Pulp/Day) 500	1000	1500
Recovery Furnaces - Smelt Tanks	2	2	3
Lime Kilns	1	2	2
Bark Boilers	1	1	1

To determine control costs for the model plants, the recovery furnace was assumed to be the only source where the present control equipment, operating at an economic optimum of 90 percent efficiency, was kept intact; venturi scrubbers were the assumed required equipment additions. Control equipment for lime kilns, smelt tanks, and bark boilers were considered replacements of existing gas cleaning equipment.

The cost parameters for the model plants are:

Model Plant (Tons Per Day Pulp)	Investment	Annual Cost	Unit Control Cost ($ Per Ton of Pulp)
500	$ 590,000	$212,000	1.28
1000	$1,020,000	$373,000	1.13
1500	$1,300,000	$576,000	1.16

The basis for the unit control cost is 330 operating days per year, 24 hours of production per operating day.

b. Impact on Typical Firm

The sample of firms from which the analysis in this section was made came from firms with disclosed financial statements. Since these were primarily large firms, the analysis of firm impact may have a built-in bias. Cash flows for each firm were approximated in the following manner. First, net income was subtracted from net income before taxes to determine the level of taxes; then the tax figure was subtracted from operating income to determine cash flow. Based on the number of plants existing in 1968 and the model which each approximated (i.e., 500, 1,000, or 1,500 tons per day), the annualized and investment control costs were determined. Then these were related to cash flows for each firm. From these, average relationships were developed.

Because of the relatively large magnitude and recent vintage of many long-term debt issues in the capital structures of sampled firms, cash flows were related not only to annualized costs but also to the initial investment costs. Annualized costs as a percentage of cash flows averaged 2.0 percent and ranged from 0.3 percent to 4.2 percent. The investment costs as a percent of cash flows averaged 5.4 percent and ranged from 0.9 percent to 10.9.

It is apparent that sufficient cash flows could be generated to meet the estimated cost of pollution control. The effect of costs on growth (net additional annual productive capacity) is expected to be small. Assuming that investment in control equipment is at the expense of other investment, the estimated decrease in growth would range from 0.07 percent to 0.17 percent depending on whether the annualized cost or the initial investment cost figures are applied.

c. Industry Composite

The most severe impact of control costs probably will be borne by the uncontrolled, marginal, nonintegrated firms. These firms are relatively few in number and are not among the larger producers in the industry.

d. Demand Elasticity and Cost Shifting Effect on the Industry

The weighted average cost of control per unit of product produced is $1.20, or about 0.7 percent of the selling price of $167.30 per ton of air-dried pulp. Although no quantitative analysis of the responsiveness of supply and demand functions to a change in cost and price of this magnitude has been attempted, a qualitative analysis of responsiveness has been made. Recent capital outlays have had the effect of reducing the growth in supply. Moreover, some kraft products are necessities and insulated, for the most part, from fluctuations in economic activity. These factors, along with vertical integration from tree cultivation to final products, the market outlook, and the nature of pulp production as a captive operation, indicate the control cost will be passed on to the consumer.

REFERENCE FOR SUBSECTION H

1. "Control of Atmospheric Emissions in the Wood Pulping Industry", Environmental Engineering, Inc., Gainesville, Florida, and J.E. Sirrine Company, Greenville, South Carolina, Volumes I-III, Contract No. CPA 22-69-18, U. S. Department of Health, Education, and Welfare.

I. Lime

1. Introduction

a. Nature of Product and Process

Limestone consists primarily of calcium carbonate or combinations of calcium and magnesium carbonate with varying amounts of impurities. The most abundant of all sedimentary rocks, limestone is found in a variety of consistencies from marble to chalk. Lime is a calcined or burned form of limestone, commonly divided into two basic products--quicklime and hydrated lime. Calcination expels carbon dioxide from the raw limestone, leaving calcium oxide (quicklime). With the addition of water, calcium hydroxide (hydrated lime) is formed.

The basic processes in production are (1) quarrying the limestone raw material, (2) preparing the limestone for kilns by crushing and sizing, (3) calcining the feed, and (4) optionally processing the quicklime further by additional crushing and sizing and then hydration. The majority of lime is produced in rotary kilns and shaft (vertical) kilns; both can be fired by coal, oil, or gas. Rotary kilns have the advantages of high production per man-hour and a uniform product but require higher capital investment and have higher unit fuel costs than most vertical kilns. The open market lime industry shows a trend toward installation of larger rotaries with a far higher capacity than vertical kilns.

b. Emissions and Costs of Control

Air pollution in the lime industry consists primarily of particulate emissions in the form of limestone and lime dust. The main source of these emissions is the calcination process; the peripheral processes of crushing, pulverizing, sizing, and conveying of the feed material are also significant potential sources. Since most modern plants adequately control the peripheral processes for economic and industrial hygiene purposes, only the kiln emissions will be considered in this analysis.

Approximately 80 percent of the lime produced in the United States is calcined in rotary kilns. The kilns vary in capacity from 50 to 700 tons per day and it is estimated that in the absence of control

10 percent by weight of the lime produced in rotary kilns is released to the atmosphere as particulate matter. Most rotary kilns are equipped with dry mechanical collectors which remove an average of 75 percent of the particulate effluent. The application of low-energy venturi or two-stage dynamic scrubbers to the smaller rotary kilns (less than 500 tons per day) and fabric filters to the larger rotary kilns (500 tons per day and larger) would allow this segment of the industry to achieve the assumed process weight rate standard at an overall control efficiency of 98.9 percent.

Vertical shaft kilns account for virtually all of the remaining lime production. These kilns tend to be smaller in capacity and to emit significantly less dust, about 1 percent of the lime produced. Few, if any, vertical kilns are presently equipped with control devices. The assumed process weight rate standard could be met by adding cyclonic scrubbers, resulting in an 88.5 percent overall control efficiency.

Particulate emissions from the lime industry in 1967 were estimated at 393,000 tons. Predicted growth of the industry would increase emissions to 609,000 tons by 1977 if control levels remained unchanged. Achievement of the assumed emission limitation by the industry would reduce 1977 emissions to 32,000 tons. The investment required to accomplish this is estimated at $28,600,000, with an annual cost in 1977 of approximately $7,200,000.

c. Scope and Limitation of Analysis

The technical and cost analysis in this section deals with the entire lime industry except plants captive to the paper industry. The analysis of economic impact is focused on those firms in the open market, since it is here that the economic effect is most clearly defined. Financial data were available for a limited number of firms; thus the financial impact of air pollution control costs had to be stated in somewhat general terms. Lime plants are almost invariably either small, closely held companies or divisions of large, highly diversified corporations. With the former, information is private; with the latter, information concerning the lime division cannot be readily segregated and analyzed.

2. Engineering Basis of the Analysis

As pointed out in the previous discussion, the air pollution problem in the lime industry consists primarily of particulate emissions in the form of limestone and lime dust. Although crushing, pulverizing, sizing, and conveying of the feed material all contribute to these emissions, the exhaust gases from the kilns represent the largest source in the industry and the only one considered in this analysis.

Rotary Kilns:

Approximately 80 percent of the lime produced in the United States is calcined in rotary kilns. A sample distribution of rotary kilns on the basis of capacity appears in Table 4-45. This table also shows, for each kiln size, the estimated control efficiency required to meet the process weight standard, the control device assumed most applicable to achieve that efficiency, and the estimated installed and annual costs of the control device.

In calculating the required control efficiencies, it was assumed that, in the absence of control equipment, 10 percent by weight of the lime produced in rotary kilns is released to the atmosphere as particulate matter. It was further assumed that the process weight rate for these kilns is 180 percent of the lime production rate.

An Industrial Gas Cleaning Institute study of past installations of control systems for rotary lime kilns indicates that wet scrubbers (especially two-stage dynamic scrubbers) have been successfully applied to many small kilns while fabric filters have been the most common control device installed on larger kilns. For this analysis, it was assumed that required control efficiencies of less than 99 percent could be achieved with a two-stage dynamic scrubber, while required efficiencies greater than 99 percent would necessitate the use of a fabric filter. As Table 4-45 shows, this assumption means that kilns of capacities less than 500 tons per day may be adequately controlled by wet scrubbers while those in excess of 500 tons per day will require fabric filters.

The estimates of installed costs for control devices came from data developed by the Industrial Gas Cleaning Institute. Figure 4-3

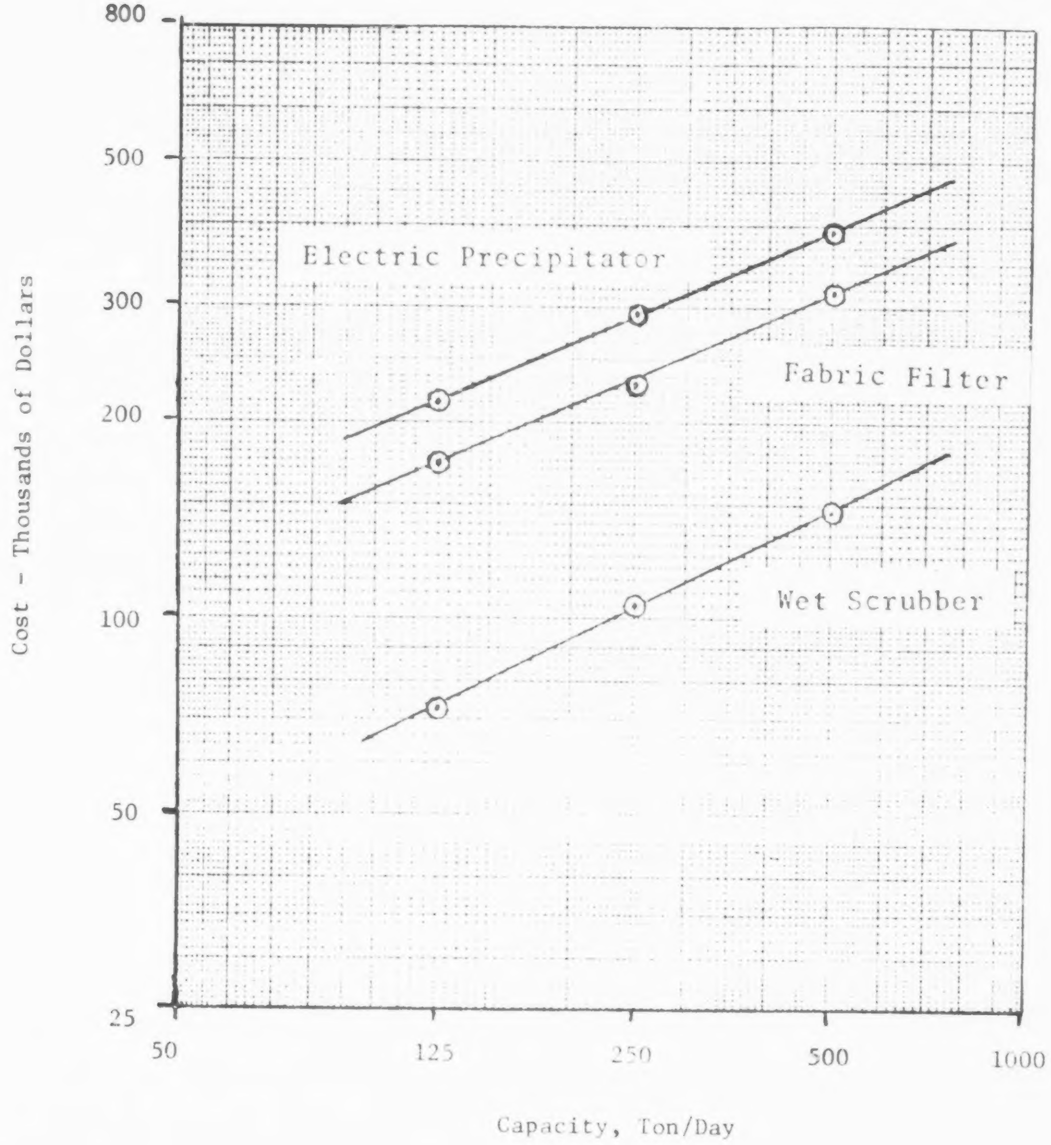


Figure 4-3. Comparison of Abatement Costs for Rotary Lime Kilns.

is a graphical summary of that data. Operating and maintenance cost estimates were derived from the same information source. Annual depreciation expense was calculated by dividing the installed cost by the expected useful life of the control device (10 years for wet scrubbers and 25 years for fabric filters). Annual interest was assumed to be 8 percent while annual property taxes were assumed to be 2 percent of the installed cost. Total annual expense is the sum of operating and maintenance, depreciation, and interest and property taxes.

From the data in Table 4-45, a weighted-average installed cost of $485 per ton of daily capacity and a weighted-average total annual cost of $118 per ton of daily capacity were calculated.

Bureau of Mines estimates put the 1967 production of lime at 17.88 million tons (excluding production by plants captive to the pulp and paper industry). Using the cost factors derived above and assuming that 80 percent of lime production comes from rotary kilns, that these kilns operate at an average production/capacity ratio of 0.85, that 30 percent of the kilns are already adequately controlled, and that capacity will grow at an annual rate of 5 percent, it was calculated that achievement of the process weight standard by rotary kilns will require an investment of $26.6 million by 1977 and an annual cost of $6.5 million in that year.

Vertical Kilns:

Vertical shaft kilns account for virtually all of the remaining twenty percent of the lime production. These kilns tend to be smaller in capacity and emit significantly less dust, amounting to only 0.4 percent of the lime produced. Satisfactory control of these kilns can probably be achieved with the installation of cyclonic scrubbers. Last year's report indicated that the weighted average installed cost of this control was $179 per ton of daily capacity and the weighted average annual cost was $64 per ton of daily capacity. In the absence of any new information, these cost factors were used again in this analysis. Applying these factors to the production of lime in vertical kilns (20 percent of the total) and assuming that the average production/capacity ratio is 0.85, the 40 percent of the kilns are already adequately controlled, and that capacity will grow at an annual rate of 5 percent, a required investment of $2.1 million by 1977 and an annual cost of $0.7 million in that year were calculated.

TABLE 4-45. CAPACITY DISTRIBUTION AND CONTROL COSTS FOR ROTARY LIME KILNS

Capacity (Tons/Day)	No. of Kilns	Required Efficiency	Control Device	Installed Cost	Operating and Maintenance Cost	Depreciation	Interest and Property Taxes	Total Annual Cost
100	4	98.1	2-Stage Dynamic Scrubber	$ 65,000	$ 4,800	$ 6,500	$ 6,500	$17,800
150	3	98.3		80,000	5,100	8,000	8,000	21,100
200	16	98.5		92,000	5,400	9,200	9,200	23,800
250	8	98.6		105,000	5,600	10,500	10,500	26,600
300	10	98.7		115,000	5,800	11,500	11,500	28,800
350	9	98.7		123,000	6,100	12,300	12,300	30,700
400	14	98.8		131,000	6,300	13,100	13,100	32,500
450	4	98.9		140,000	6,500	14,000	14,000	34,500
500	18	99.0	Fabric Filter	315,000	30,000	12,600	31,500	74,100
550	6	99.1		330,000	32,400	13,200	33,000	78,600
600	2	99.1		345,000	34,800	13,800	34,500	83,100
650	4	99.2		360,000	37,200	14,400	36,000	87,600
700	2	99.2		370,000	39,600	14,800	37,000	91,400

3. Industry Structure

a. Characteristics of the Firms

The United States lime industry is conventionally divided into two sectors--open market and captive. For 1967 approximately 75 firms sold lime commercially from 121 active plants (one in Puerto Rico). Very small pot kiln plants that operate sporadically and on a local basis were not considered. Open market production for the year amounted to 11.46 million tons of lime, or nearly 64 percent of the output for the entire industry. The captive sector of the lime industry was represented by 104 active plants in 1967. Captive production totaled 6.51 million tons for the year, equaling 36 percent of total output.

The sizes of plants in the lime industry, classified using production records for 1967 by the U.S. Bureau of Mines, are shown in Table 4-46. The numbers of commercial (121) and captive (104) plants are not additive, since 16 plants produce for both sectors.

TABLE 4-46. NUMBER AND PRODUCTION OF DOMESTIC PLANTS, 1967

Annual Production (Short Tons)	Number of Plants	Production (1000 Tons)	Percent of Total
Less than 10,000	56	284	2
10,000 to 25,000	37	604	3
25,000 to 50,000	29	1,020	6
50,000 to 100,000	29	1,890	10
100,000 to 200,000	25	2,810	16
200,000 and over	33	11,366	63
TOTAL	209	17,974	100

Some of the larger producers have been covered in the trade journals and several have reported capacities of 1,000 to 1,500 tons per day, with the largest known at 3,000 tons per day (over 900,000 tons per year). Very small plants are seldom mentioned in the literature, but it is almost certain that some of these plants operate with only a single, small capacity (5 to 20 tons per day) vertical kiln. The average plant for 1967 produced approximately 86,000 tons per year (roughly 275 tons per day). Average plant size has increased throughout the sixties, and for 1969 it had increased to 100,000 tons per year (330 tons per day).

b. Operating Characteristics

Based upon production and capacity figures for a sample of 42 plants, it is estimated that lime producers operated at slightly over 85 percent of capacity in 1967. This is a healthy operating rate, especially considering that quicklime is quite perishable and should be consumed within a month or two after manufacture.

Before 1962, the industry normally faced excess capacity (65 to 70 percent operating ratio) and low profitability. With the massive introduction by the steel industry of the basic oxygen process, however, lime for steel flux usage nearly tripled and in general lime producers recorded a prosperous decade.

c. Resources

Raw limestone occurs in virtually every State of the United States, and the country's supply is so vast that a total is incalculable. However, the deposits of some States lack the necessary quality or economic accessibility and do not warrant further processing. Both captive and open market lime were produced in 41 States in 1967. Most lime producers own their sources of supply and have ample reserves, but the cost of obtaining stone or kiln feed varies widely and is an important segment of overall manufacturing costs.

Labor costs represent on the average slightly under 20 percent of sales. Rising wages in recent years have caused a trend toward capital intensiveness and automation, a trend that is expected to continue. In 1960 the open market sector employed 6,200 workers at an average wage per man-hour of $2.35. For 1967, these figures were 5,800 and $3.02. Over the same period, production rose from 8.2 to 11.5 million tons.

4. Market

a. Distribution

Since raw materials are widely distributed and transportation costs can quickly become prohibitive for a low value-to-bulk produce, lime plants tend to locate near major markets. In contrast to cement, for example, most lime is shipped directly from the plant instead of from distribution terminals. Normally, lime is shipped not more than 200 to 300 miles from the plant. A few firms have developed cheap water transportation, and shipments from the Mississippi River to east and west coast cities occur.

Lime, now regarded as a basic industrial chemical, is used for a variety of purposes. The distribution of output by consumers for 1967 is shown in Table 4-47 below.

TABLE 4-47. LIME SOLD OR USED IN THE UNITED STATES, 1967 [1]
(Thousand of Short Tons)

Use	Open Market	Captive	Total	Percent of Total
Agriculture	174	0	174	1
Construction	1,433	[2]	1,433	8
Chemical & Other Industrial	1,593	4,369	5,962	33
Metallurgical	4,452	1,148	5,600	31
Paper and Pulp	878	92	970	5
Sewage Treatment	322	49	371	2
Sugar	27	536	563	3
Water Softening & Treatment	1,019	4	1,023	6
Refractory Lime	1,565	315	1,880	10
TOTAL	11,461	6,513	17,974	100

[1] Totals may not add because of rounding.

[2] Data withheld to avoid disclosing individual confidential data.

b. Competition

Traditionally, the lime industry has been reported to be intensely intracompetitive. There are several possible reasons to explain this condition: (1) Historically, the industry often functioned at low operating rates (65 to 70 percent of capacity) and this invariably led to higher costs per ton of output and a "buyers' market"; price wars, even to the extent of prices falling below the cost of production, have been documented. (2) Because quicklime is reactive to atmospheric moisture and should be used quickly--within a month or two after manufacture--or become waste, the firms faced some pressure to dispose of it. (3) Variance in quality and consistency of the final lime product from producer to producer is an added factor in the competitive picture.

External competition is minimal. Lime has few contenders. For its use as an alkaline reagent in chemical production, as a flux in steelmaking, and as a cheap source of carbon dioxide, there are no alternate materials to replace lime or limestone within a comparable price range. In the construction sector, however, lime has lost considerable ground to cement, gypsum plaster, and gypsum wallboard, and finely crushed limestone has largely replaced lime in agricultural uses because it lasts longer in the soil and requires less frequent application.

Foreign trade has little importance to the U.S. lime industry. Net imports for 1967 amounted to only 70,000 tons (less than 1 percent of the market). Trade is significant only near the Canadian and Mexican borders.

5. Trends

a. Production

Excluding a slight decline in 1967, the lime industry has set a record level for production in every year over the past decade. For 1970, output stood at an estimated 21.15 million tons, an impressive increase of nearly 64 percent from the 1960 level of 12.94 million tons--a compounded growth rate of just over 5 percent annually. Open market production has led the way with a 5.5 percent increase per annum; captive tonnage meanwhile increased 4.5 annually. This remarkable record in the sixties was spurred by several new and expanded uses of the product, chief of which was the change to the basic oxygen furnace in the steel industry. Open hearth furnaces require about 20 pounds of lime for each ton of steel produced; the basic oxygen furnaces require about 150 pounds. Increased usage of lime was also seen in soil stabilization, sewage and water treatment, and water softening. Optimism prevails in the industry and open market production is expected to continue to grow at a healthy pace into the seventies.

b. Price, Sales, and Profits

Lime has always been a low-price product, and rapid increases in price have not occurred. The average F.O.B. plant price per ton on a bulk basis stood at $13.35 in 1960. Small increases occurred yearly until a peak of $13.87 was reached in 1965. Average price then dipped back down to $13.27 in 1966, and since then has risen back up to $13.89 per bulk ton in 1969. The 1966 depression in the price level may partially have been the result of hard bargaining by steel firms for lower prices, or that a number of new efficient plants went on line during this period, as well as new and larger capacities at established firms. Continuation of depressed prices is unlikely, considering a strong demand and rising production.

6. Economic Impact of Control Costs

a. Industry Composite

Many of the older, less efficient plants in the industry, which have not installed high efficiency control equipment, are expected to feel the greatest effect from the outlays for pollution abatement. It is estimated that by 1967 the lime industry had already invested approximately $10 million in equipment for control of kilns and was experiencing an annual cost of $2.7 million.

b. Impact on a Plant

The impact of the added costs of air pollution control was analyzed for four model plants, constructed to represent typical operating patterns over a wide range of capacities with a variety of kiln combinations. The plants described here do not necessarily exist, but are based on known characteristics within the lime industry.

Basic descriptions and financial data for these model plants are shown in Tables 4-48 and 4-49.

TABLE 4-48. BASIC DESCRIPTION, LIME PLANTS

	Model Plants			
Characteristic	Plant 1	Plant 2	Plant 3	Plant 4
Capacity (Tons per year)	89,100	89,100	173,250	330,000
Construction Cost, Without Control, 1969	$2.0 mil.	$2.6 mil.	$4.3 mil.	$7.7 mil.
Kilns (Number, Type, Size in Tons/Day)	3-Vertical-90	1-Rotary-270	6-Vertical-50 1-Rotary-225	1-Vertical-400 1-Rotary-600
Production at 90 Percent Operating Rate (Tons/Year)	80,190	80,190	155,925	297,000
Average Price Per Ton (F.O.B. Plant, Bulk, 1969)	$13.89	$13.89	$13.89	$13.89
Control Investment Cost	$51,000	$115,000	$170,000	$385,000
Annualized Control Cost	$18,600	$ 25,200	$ 45,000	$ 86,500

TABLE 4-49. INCOME STATEMENTS, LIME PLANTS
(Thousands of Dollars)

	Plant 1		Plant 2	
	Before Control	After Control	Before Control	After Control
Sales	1,114	1,114	1,114	1,114
Cost of Goods Sold	1,068	1,068	1,066	1,066
Added Control Cost	0	19	0	25
Taxable Income	46	27	48	23
Income Tax	12	7	12	6
Net Earnings	34	20	36	17
Cash Flow	134	125	166	159
Net Earnings/Ton	0.424	0.249	0.449	0.212
Cash Flow/Ton	1.671	1.559	2.070	1.983
Control Cost/Ton	0	0.237	0	0.312
Return on Investment	2.97%	1.96%	2.45%	1.56%

	Plant 3		Plant 4	
	Before Control	After Control	Before Control	After Control
Sales	2,166	2,166	4,125	4,125
Cost of Goods Sold	2,000	2,000	3,879	3,879
Added Control Cost	0	45	0	86
Taxable Income	166	121	246	160
Income Tax	55	35	91	52
Net Earnings	111	86	155	108
Cash Flow	326	318	540	511
Net Earnings/Ton	0.712	0.552	0.522	0.364
Cash Flow/Ton	2,091	2.039	1.818	1.721
Control Cost/Ton	0	0.289	0	0.290
Return on Investment	4.34%	3.62%	3.46%	2.35%

The relationships shown in the preceding income statements indicate the magnitude of air pollution control costs for lime plants with vertical kilns (Plant 1), a rotary kiln (Plant 2), and various kiln combinations (Plants 3 and 4). These figures indicate the impact which may be expected for the large number of single plant firms. Multiple plant firms may be approximated by multiplying individual plant costs by the number of plants.

c. Impact on the Firms

Approximately 20 percent of the firms in the open market sector of the lime industry have interests in other areas such as construction materials, cement, gypsum, chemicals, and drugs. However, the vast majority (80 percent) are relatively small companies which base most of their sales on lime and lime products. If not passed on in the form of price increases, the added costs of air pollution control would in general have a detrimental effect on the earning power of these smaller firms due to low profit margins (3 to 5 percent of sales before control is shown in the examples of the preceding section), and quite a few of the firms occasionally show losses from operations. The additional burden of air pollution control would normally lower income by at least 20 to 40 percent and, in the worst situation, could swallow all profits. The captive sector of the industry would probably feel less effect as their lime plants are only small parts of much larger operations.

Based on a study of the balance sheets of approximately 20 open market firms, it does not appear that most companies will face difficulties in raising the necessary capital for pollution control. The typical balance sheet shows a strong current ratio, adequate working capital, and low levels of debt. Lime producers have several ways to raise funds including cash flow from operations, term loans, and bank revolving credit agreements; most companies have reasonable credit arrangements and good relations with their bankers. There are some, however, who do appear unprofitable, have poor credit relations, and would probably have trouble raising the necessary capital.

d. Demand Elasticity and Cost Shifting

Lime is one of the starting materials for a wide variety of products. Because lime is essential in the manufacture of chemicals, metals, and thousands of other industrial products, its demand is not highly elastic with regard to price; therefore, the lime industry should lose little of its market to substitute products, even if the entire added costs of pollution control are passed on to purchasers.

Intraindustry competition is normally characterized as severe, and selective price increases by some firms would likely cause others to move into the market. There are exceptions; for example, in some marketing areas, isolated producers face little competition and should be able to pass on the added costs. With a rise in prices, lime producers in general would find their marketing areas expanding or contracting depending upon the efficiency of their operations.

For the past several years the demand for lime has been strong and output has been increasing, and these trends are expected to continue. With a favorable outlook for the coming decade, it is expected that by 1977 the lime industry in general should be able to shift most of the control cost into price. This conclusion is bolstered by the following considerations: (1) all lime producers will be affected by pollution control, and the annual cost per unit of output is reasonably constant for most plants (i.e., in the range of $0.25 to $0.30 per ton); (2) with the costs of control having a moderate to severe effect upon the earnings of most firms, the industry in general should not be able to tolerate the decline in income; (3) if the cost of control were to be passed on, the resulting price increase would be rather small (about 2 percent per ton, based upon the 1969 average bulk price at the mill of $13.89 per ton); (4) price increases would be little affected by external competition and substitution; and (5) competition within the industry is keen but by no means uniform throughout the country. To the extent that some firms are larger and more efficient, they may be better able to raise prices.

e. Effect on Industry

Many of the older or very small plants are obsolete from both efficiency and profit points of view and may be abandoned if faced with high control costs. To compensate, production should increase from the larger kilns and the industry operating ratio would thereby increase. Firms which have been operating close to capacity may launch expansion programs as a result of increased demand.

A second effect of control may be a renewed interest in vertical kilns. The lower relative costs associated with controlling the large vertical kilns coupled with their excellent thermal properties and lower investment costs may make them more attractive in some applications. The trend toward high capacity rotaries may be slowed somewhat.

The open market sector of the lime industry may benefit by the imposition of control costs. The added expense may make captive production less desirable for those industries needing large amounts of lime--most notably steel and pulp and paper.

It should also be noted that the lime industry could benefit greatly from the national concern for the environment. Specifically, the power industry may require large amounts of lime by 1980 in the form of an additive to control sulfur oxides from the burning of fossil fuels. Although the amounts to be used are far from certain, it is possible that such pollution control efforts will make a significant new market for the lime industry.

REFERENCES FOR SUBSECTION I

1. Industrial Gas Cleaning Institute, "Study of Technical and Cost Information for Gas Cleaning Equipment in the Lime and Secondary Non-Ferrous Metallurgical Industries", 1970.

2. Midwest Research Institute, "Handbook of Emissions, Effluents, and Control Practices for Stationary Particulate Pollution Sources", 1970.

3. National Air Pollution Control Administration, "Air Pollutant Emission Factors", 1970.

4. United States Department of the Interior, "Bureau of Mines Yearbook", 1967.

J. Nitric Acid

1. Introduction

a. Nature of Product and Process

Nitric acid is an important material in the manufacture of fertilizer-grade ammonium nitrate and explosives. The acid is produced by oxidation of ammonia, usually under high pressure and temperature over a platinum catalyst, forming nitrogen dioxide (NO_2) and nitric oxide (NO). The gaseous products are removed from the reactor, cooled to form more NO_2, and are sent to an absorption tower to form the acid product. The process forms an acid of approximately 60 to 65 percent strength, which is sufficient for ammonium nitrate production, and may be upgraded to 99 percent strength by one of several concentration processes. Both the ammonia reactor and the absorption tower are operated under high pressure, which favors heavy production of NO and NO_2 with minimum amounts of equipment. Oxidation of ammonia and final reduction of tail gas compounds are highly exothermic reactions which produce the heat and energy needed to satisfy demands in other parts of the plant.

b. Emissions and Cost of Control

Nitrogen oxides, the primary pollutants of concern in the production of acid, are essentially emitted from the absorption tower. The purpose of this tower is to absorb NO_2 with water in countercurrent flows. The original gas stream, containing about 8 percent NO_2, possesses 0.3 to 0.5 percent NO_2 and NO combined on leaving the tower. The balance of the gas contains 2 to 4 percent oxygen and 95 to 97.5 percent nitrogen.

Many plants practice partial pollution abatement (decolorization) in accordance with local regulatory agencies. The NO_2, which produces a characteristic reddish-brown plume, is reduced to NO by reaction of the tail gas with methane or propane over a catalyst. Abatement of NO is required by the assumed emission standard. Uncontrolled emissions before decolorization are 45 pounds of NO_x per ton of product. The assumed emission standard is 5.5 pounds per ton of acid produced for existing plants. New plants are assumed to perform at least as well.

Nitric acid plants emitted 145,000 tons of NO_x in 1967. Without the Act, the emissions would be 229,500 tons in FY 1977 based on a 4.5 percent growth rate through 1970, and 5 percent thereafter. Implementation of the Act would reduce the emissions to 25,000 tons by FY 1977. The nitric acid industry would be required to spend $37 million for investment and $14 million for annual expenditures for full implementation by FY 1977. These estimates are based on catalytic reduction technology. For many pre-1960 plants, it is doubtful whether this technique will be used. More likely, such plants will be shut down.

2. Engineering Basis of Analysis

The application of catalytic reduction technology was based on the assumption that only modern, large plants would and could accept such technology without a significant overhaul in the original plant equipment. For the purpose of cost estimation, plants built before 1960 were assumed to shut down rather than add the necessary equipment for abatement.

Based on a total industry population of 194 nitric acid plants in 1970, encompassing some 85 establishments, 10 plants are considered to have met the assumed emission standard. An additional 52 plants practice decolorization and hence are in a position to abate the full route because of their existing power recovery capabilities, which are necessary to decolorize via a catalytic combustor. Of the remaining 132 plants, which are totally uncontrolled, 63 were assumed to add the necessary control equipment to their existing plants. This decision was a compromise to separate those who would shut down production altogether; those who would go to great expense and add such equipment as new absorption towers, heat exchangers, waste heat boilers, and turbine expanders; and those who would build new plants with the necessary abatement equipment to meet all required emission standards.

The model plants and attendant costs are stated as follows:

Model Plant	Plants	Investment	Annual
150 ton per day	63	$300,000	$ 80,000
300 ton per day	52	$400,000	$120,000

The costs include investments for a single high temperature combustor, waste heat boiler, catalysts, piping, and instrumentation. It is assumed that sufficient make-up power is available from the compressor. No credit was given for steam exports available from the waste heat boiler.

Estimates for a typical 300-ton-per-day plant that does not practice power recovery (plants built before 1960) have been as high as $1.5 million for application of high temperature or dual combustion technology. If a plant were faced with such an investment, obviously it would shut down. For such plants, molecular sieve absorption offers an attractive alternative. Investment for this alternative is approximately $250,000 for a 300-ton-per-day plant. Operating costs are comparable to those for catalytic reduction abatement. In addition, collected NO_x pollutants can be recovered as usable nitric acid.

3. Industry Structure

a. Characteristics of the Firms

Nitric acid is almost entirely a captive industry, producing an intermediate for manufacturing fertilizers, commercial explosives, and other goods. In addition, the Federal government owns many plants for producing ordnance products. Present ownership of acid plants (1970) is 80 percent controlled by large, integrated firms--chemical producers and oil and gas companies. The remaining 20 percent are owned by farm cooperatives and small, chemical fertilizer-oriented companies.

As of 1970, there were 87 commercial plants owned by 35 firms. Many plants are owned by firms with ammonia and ammonium nitrate facilities. Companies producing fertilizer often have urea and ammonium phosphate plants as well as nitric acid and ammonium nitrate facilities at the same location. Urea is produced directly from ammonia, bypassing the acid process, and its use provides flexibility to a firm's fertilizer operations. Thus, horizontal and vertical integration is evident in the character of the firms owning acid plants.

b. Operating Characteristics

The nitric acid industry maintained a balance between productive capacity and output from 1960 to 1968. Profits were maintained with operations running at 80 to 90 percent of capacity. During the sixties, expansion grew at an annual rate of 9.5 percent, in step with demand for ammonium nitrate. Additions to capacity surged in 1967, with a 13.7 percent increase over 1966. However, sales of fertilizers sagged in 1968 and 1969, and the industry was faced with idle facilities. Apparently, sagging prices for grains and bad weather were responsible for the slowdown in sales.

c. Resources

Ammonia is the most important compound in the production of nitric acid. Based on a price of $35 per ton, ammonia constitutes 51 percent of the manufacturing costs. Availability of ammonia at low cost depends on the hydrocarbon fuel source used in its synthesis. Natural gas, refinery off-gas, and naptha are the important feed sources used in this country. Improved technology geared to large production of ammonia through the application of better catalysts and turbine-driven centrifugal compressors has lowered the costs of manufacture; these vary from $35 per ton produced in an economical captive plant to $75 per ton for the delivered, merchant product.

Catalysts of platinum-rhodium formulations are used in the oxidation of ammonia and the reduction of tail gas nitrogen oxides. Catalyst losses as a result of the ammonia oxidation may vary from $0.40 to $2.20 per ton of acid. Based on the manufacturing cost of acid at $19.50 per ton, catalyst losses may vary from 2 to 11 percent of the manufacturing cost, plus interests and renewal costs. The impact of abatement adds significance to the catalyst requirements, as catalysts for nitrogen oxides must be carefully monitored during process operation. In addition, the catalyst units for abatement must be renewed at least once every two years.

Fuel, utilities, and labor appear to be insignificant items in the acid manufacture itself. Transportation costs are important. For the firm producing both ammonia and nitric acid, it is much cheaper to ship ammonia; one ton of 57 percent nitric acid requires only 0.17 tons of ammonia. Hence, an ammonia plant located near feedstock sources and nitric acid facilities located near end use points would result in transportation savings.

4. Market

a. Distribution

Synthetic ammonia is normally produced near oil and gas fields in California and the gulf coast of Texas and Louisiana. Ammonia is usually stored in pressure tanks as a liquid. It is more easily stored and it is cheaper to ship to end use points than nitric acid.

The distribution of nitric acid consumption is as follows:

Ammonium nitrate fertilizers	62.4%
Ammonium nitrate explosives	8.0%
Miscellaneous fertilizers	2.4%
Dinitrotoluene (urethanes)	1.4%
Nitrobenzene (rubber chemicals, urethanes, etc.)	1.4%
Commercial explosives and propellants	16.8%
Miscellaneous direct uses	5.2%
Miscellaneous compounds	2.4%

Nitric acid plants for the most part are concentrated near markets in the Midwest for nitrate fertilizers. Plants often convert the acid directly, at the same location, into ammonium nitrate. Prilled nitrate can be mixed with granulated concentrates of phosphate and potash to produce complete fertilizers.

Fertilizer-grade ammonium nitrate can be converted into explosives for commercial uses such as coal mining, all types of construction, mining, and quarrying.

Nitric acid destined for final industrial consumption goes into manufacture of urethane foams, both rigid and flexible; aniline for rubber, chemicals, dyes, pharmaceuticals, and hydroquinone; and nitrous oxide for anesthetics and food aerosols.

b. Competition

Nitric acid is not a merchant chemical of any significant volume; that is, approximately 10 percent is sold in a competitive market. The marketability of its end products determines the degree of competition for the industry.

Use of ammonium nitrate in fertilizer seems to be the most competitive area. A very close substitute is urea. It is high in nitrogen content, can be prilled for intimate mixing with other fertilizer materials, and is not as subject to leaching as ammonium nitrate. Therefore, nitric acid usage in fertilizers is price competitive with urea. Nitric acid is used to a small extent in acidulation of phosphate rock; however, its use on a large scale is limited due to an abundant supply of sulfuric acid at much lower cost than for nitric acid.

Nitric acid usage in the fertilizer business seems limited due to the growing use of anhydrous ammonia applications in mixed liquid fertilizers. As liquids gain more acceptance with farmers, anhydrous ammonia can be used directly in preparing a liquid application, thus foregoing the expense of acid production.

In the industrial applications of nitric acid, there seems to be little potential for substitution. Products such as explosives, dyes, and the urethane foams can be produced only from nitric acid derivatives.

5. Trends

a. Capacity and Production

Since 1967, the nitric acid industry has been faced with excessive capacity due to overexpansion of capacity and a sagging market for fertilizers. Few new plant additions are expected during the next 5 years as the industry is expected to rationalize the present imbalance in supply and demand.

Although demand for acid is expected to grow at an annual rate of 5 percent, growth in capacity is expected at an annual rate of only 1 percent. Demand for fertilizers and explosives will be consistent with the 5 percent growth pace. Urethane demand is expected to grow at a rate of 25 percent through 1975; however, its portion of the acid market is small. Above average growth rates are expected for dyes, pharmaceuticals, etc., but again these absorb only a minor portion of acid production.

If nitric acid remains available at present low prices, possible new uses may become a reality. Because of its chemical reactivity, nitric acid does offer itself as a potential in formulating new plastic products.

b. Prices, Sales, and Profits

Prices for nitrogen nutrients paid by farmers have steadily declined during the 10 years ending in 1970. Ammonium nitrate, for example, has dropped from \$2.44 per unit (1 unit = 20 lbs.) in 1960 to \$1.79 in 1970. Most of this price erosion has been due to the increasing availability of cheap ammonia through improved technology, but nitric acid price erosion in the late 1960's has been due to overcapacity. Prices for ammonium nitrate, as paid by farmers, are a good barometer of trends in nitric acid prices.

As the operating ratio of the industry improves, prices and profits should recover during the next 5 years. In 1969, output was only 72 percent of capacity. The break-even point occurs when production runs at about 80 percent. Assuming that nitric acid sales grow by 5 percent and annual capacity by 1 percent, industry production should exceed the 80 percent operating ratio sometime in 1972 or 1973.

6. Economic Impact of Control Costs

a. Impact on Plant

Since a viable nitric acid market does not exist, the impact of control must be related to the end products. For purposes of illustration, ammonium nitrate was selected because it comprises two-thirds of the market for nitric acid.

The impact of added costs for pollution control was determined for a 380-ton-per-day ammonium nitrate facility with its own captive nitric acid support facility (300 tons per day) under two options. One option (Plant A) represents an existing acid plant requiring a high temperature combustor addition to the original plant. The second option (Plant B) assumes a new acid plant designed for required abatement via high temperature combustion. Although not shown here, other designs in combustion technology, such as the dual stage combustion system, may be expected to perform effectively at comparative cost.

The control costs per ton of nitric acid under the two options are shown below in Table 4-50.

TABLE 4-50. BASIC PLANT DESCRIPTION, NITRIC ACID

	Nitric Acid - Ammonium Nitrate Systems Plant A	Plant B
Nitrate Capacity (Tons/Yr)	125,400	125,400
Nitrate Production (Tons/Yr)	112,900	112,900
Plant Investment	$5,400,000	$5,400,000
Control Investment	$ 400,000	$ 50,000
Added Control Cost[1/] ($/Ton Acid)	$ 1.34	$ (0.05)[2/]

[1/] Includes depreciation and interest charges calculated at 20 percent before taxes on control investment.

[2/] Steam credits will more than compensate for capital and catalyst changes.

The existing acid plant would incur an added cost of $1.34 per ton of nitric acid versus no cost for a new plant.

The impact of pollution control on the ammonium nitrate-nitric acid complex under the two options is shown in the following income statement exhibited in Table 4-51.

The cash flow decreases only by a negligible amount as a result of added control costs. This is important to an industry which already experiences a low return on investment (on the order of 5 percent after taxes). The significant drop in earnings for the facility with an existing acid plant will certainly discourage similar firms from upgrading existing facilities, especially older acid plants with little or no book value.

TABLE 4-51. ANNUAL INCOME STATEMENT
(THOUSANDS OF DOLLARS)

	Plants A&B (Without Control)	Plant A (After Control)	Plant B (After Control)
Sales	$4,853	$4,853	$4,853
Cost of Goods Sold	4,470	4,590	4,531
Added Control Cost	0	120	(4)
Net Income Before Tax	384	264	388
Income Taxes	173	119	175
Net Earnings	211	145	213
Cash Flow	751	725	758
Net Earnings/Ton Product	$2.05	$1.28	$2.05
Change in Earnings,%	0	-29	0
Control Cost, % of Sales	0	2.5	0

b. Impact on Firm

Well over 80 percent of the firms involved in nitric acid production have interests in many other areas including oil, natural gas, and a wide variety of chemicals. Because of this diversification and the size and financial strength of the firms involved, abatement costs should have little impact on total earnings.

c. Demand Elasticity and Cost Shifting

Fertilizers in general and nitrogen fertilizers in particular have been among the hardest hit of the chemical categories over the past few years. Overcapacity and retarded sales have combined to produce poor returns and restricted profits. The future is expected to be a little better, but producers remain pessimistic and there seems little hope for substantial improvement before 1973.

For the past several years, demand for nitric acid and ammonium nitrate has fallen short of supply capabilities. Competition has been stiff, prices have been at a low level, and consequently, air pollution control costs have generally been absorbed by the manufacturers. With an uncertain future ahead, it is expected that abatement costs will continue to be absorbed. Demand for ammonium nitrate is elastic with regard to price, because the farm community can be expected to switch to substitutes such as anhydrous ammonia and urea if ammonium nitrate prices increase relatively; in fact, production and consumption patterns of nitrogenous fertilizers in the past several years have shown a movement toward such substitues. Ammonium nitrate and nitric acid both face strong competition and must be expected to absorb pollution control expenses.

d. Effect on Industry

Pollution control equipment including catalytic reduction has been included in virtually all new nitric acid expansions in the past few years. Added exnenses for catalysts and capital changes for the most sophisticated designs are more than compensated for by heat recovery. On the other hand, upgrading pre-1960 plants may prove uneconomic. Costs for these plants will be in excess of estimates shown in Table 4-50 and Table 4-51; hence, many such plants will be shut down. Plants built since 1960 that incorporated partial abatement (decolorization) will incur costs similar to the estimates shown in this analysis for existing plants.

The fertilizer supply and pricing situation of the past few years has had severe financial effects on the smaller producing companies, and a spate of mergers and takeovers has followed to consolidate and rationalize the industry. It is expected that obsolete plants will be replaced with new modern plants capable of meeting the assumed emission and new source performance standards.

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K. Petroleum Refining and Storage

1. Introduction

Three processes in petroleum refining have been identified as the major sources of atmospheric pollutant emissions. These are storage of crude oil or refined products, combustion processes, and catalyst regeneration. In addition, significant emissions are released by certain bulk storage tanks where petroleum products are stored for distribution. The analysis in this section is limited to the nature, control, and costs of these four sources.

2. Engineering Basis of the Analysis

a. Petroleum Refining

(1) Sulfur Recovery Plants

Sulfur oxide emissions were controlled by installing sulfur recovery plants at those refineries which did not already have them. The size of the sulfur recovery plants was based on each refinery's capacity and on estimated sulfur oxide emissions.

Since specific data on the composition of a refinery's crude oil or its exact processing techniques were not available, a general sulfur dioxide emission factor of 70 long tons per 100 thousand barrels of crude oil throughput was used. Variations in this emission factor were made based on crude oil sulfur content. Thus, in the gulf coast and California areas, this factor was reduced by 6 percent; on the east coast it was increased by 42 percent; and it was not changed for the balance of the country. Since operation of sulfur plants smaller than 4 tons per day is not economically feasible, the smaller refineries (sulfur dioxide emissions less than 13.8 tons per day) were not included in the cost estimates.

To meet the sulfur recovery standard denoted in Appendix I, tail gas scrubbing was costed. Table 4-52 indicates the investment and annual costs developed. Note that annual costs are calculated only for the scrubbing section. It is assumed that sulfur plants result in a zero total net annual cost. For the scrubbing section, the relationship Annual Cost = 0.28 Investment was used.

TABLE 4-52. SULFUR PLANT AND TAIL GAS SCRUBBING COSTS

Sulfur Plant Capacity Long Tons/Day	Sulfur Plant Costs (With Tail Gas Scrubber) ($1,000)	Scrubber Alone ($1,000)	Annual Cost ($1,000)
10	410	176	48
100	1,500	640	182
300	3,400	1,420	400
1000	8,400	3,600	1,000

Sources of Data: (a) Oil and Gas Reporter, October 28, 1968.
(b) Private communication with Dr. D. K. Beamon of the Ralph M. Parson Company.
(c) Paper presented at 8th Annual Meeting of Southern California Sector of AIChE, April 20, 1971.

(2) Catalyst Regenerators

To meet the particulate regulation, only fluid catalytic cracking (FCC) units larger than 10 thousand barrels per day required additional controls. All smaller FCC units and all Thermofor (TCC) and Houdriflow (HCC) catalytic cracking units can meet the regulations with existing controls. Control costs were based on using a high-efficiency electrostatic precipitator; operating and maintenance costs were based on the size of the unit; and a

20 percent capital plus depreciation charge was used to derive the annual costs.

For controlling carbon monoxide and hydrocarbon emissions, the cost of a carbon monoxide (CO) boiler was estimated for each FCC unit. The HCC units already have CO boilers, and TCC units with their lower CO emissions are not generally amenable to control with a CO boiler and were not included in the cost estimate. Only 50 percent of the capital investment for these boilers was charged as an air pollution control cost since steam is generated in these units for inplant purposes. Annual charges were also not included as an air pollution cost since they are a general plant cost.

CO boiler costs were estimated according to the heat content of the exit gas stream and the available boiler cost as indicated by Babcock & Wilcox, and Bauman. Locations of existing CO boilers, when known, were taken into account.

The installed cost of retrofitting a CO boiler into an existing installation would be 1.2 x Installed Cost (I) of a CO in a new facility. These are the usually quoted cost figures. Annual cost (A) of CO boilers was calculated using the following relationship:

$$A = 0.2 \times 1.2 \times 0.5\ I\ .$$

This relationship reflects the following factors:

(1) An offset equal to the annual OMR is allowed.

(2) Only 50 percent of boiler installed costs is considered as an air pollution control expenditure.

(3) Depreciation and other capital charges of 20 percent per annum.

In previous reports in this series it was assumed that recovered catalyst would offset operation and maintenance costs. However, after consultation with EPA personnel, it was determined that this is not a completely valid assumption. Therefore, a factor of 0.16 x Installed Cost was included in all precipitator cost calculations.

Sulfur dioxide is also emitted at concentrations in the 500 to 1000 ppm range, but these emissions are currently not controlled, since it is claimed that no economical means exists for reducing this emission.

Precipitator costs were based on the gas flow rate leaving the catalyst regenerator. Based on limited data (See References 1,3, and 4 at end of this Subsection), the following relationship between barrels of total feed and exit gas rate was determined:

$$\text{acfm} = \frac{2830 \text{ acfm}}{1000 \text{ bbl/day}} \times \text{feed rate (in 1000 bbl/day)} + 75{,}000 \text{ acfm} .$$

With the exit gas rate known, cost functions relating cost and feed rate were prepared and used to determine total and annual charges. (See Figure 4-4.)

Emissions of particulates from FCC units with normal process controls, but without electrostatic precipitators for air pollution abatement purposes, were based on 6.25 pounds of particulate per 100 barrels (0.10 pounds per ton of catalyst); particulate emissions from Thermofor and Houdriflow units were based on 0.52 pounds per 1000 barrels (0.04 pounds per ton of catalyst). Estimates of controlled emissions were based on an electrostatic precipitator collection efficiency of 82 percent.

CO boiler costs are shown in Figure 4-5. These costs could vary depending on the amount of supplementary fuel used to generate plant steam; however, the costs shown do represent that portion of the cost chargeable to air pollution control.

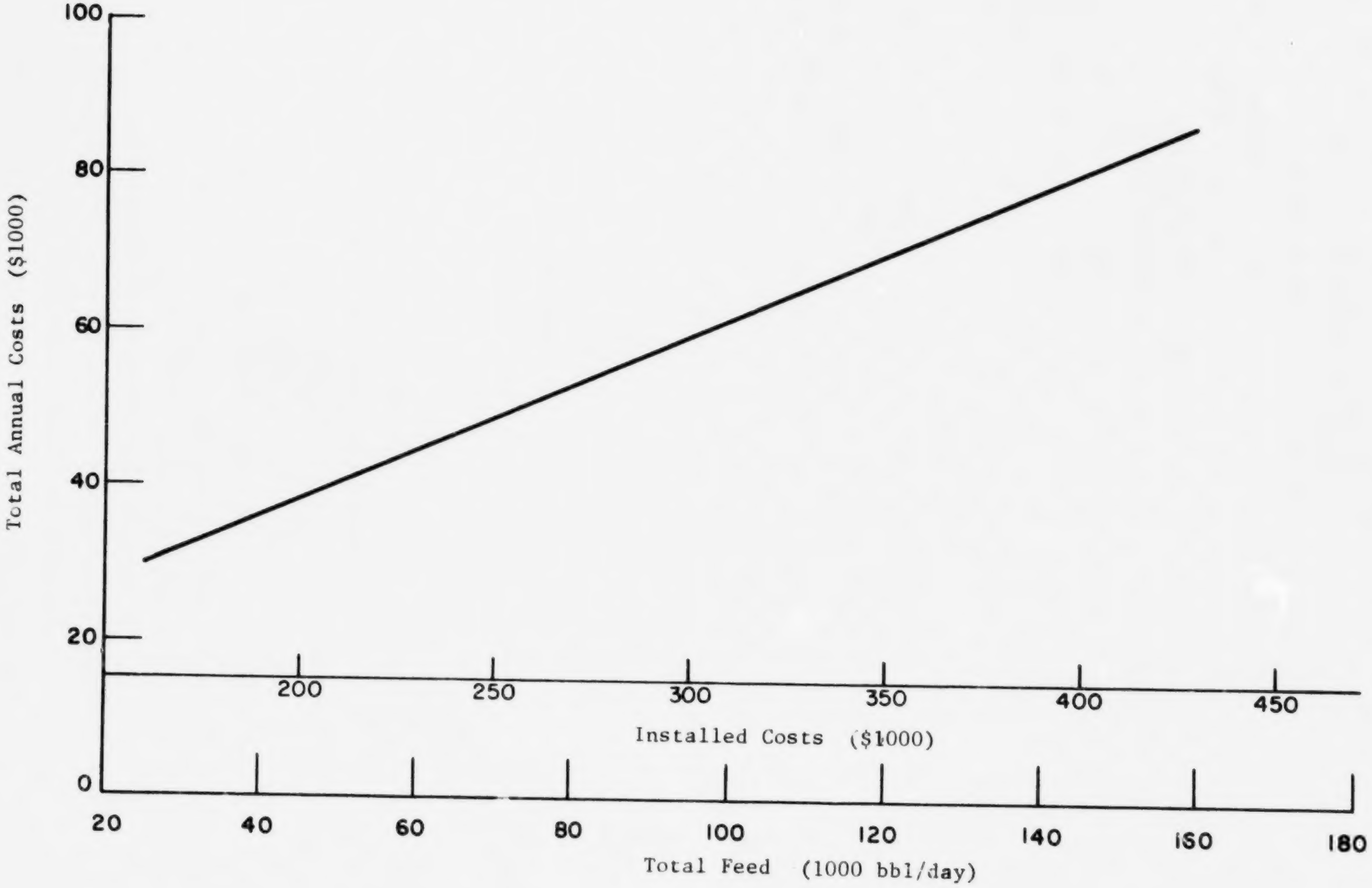

Figure 4-4. Annual and Installed Costs for Electrostatic Precipitators.

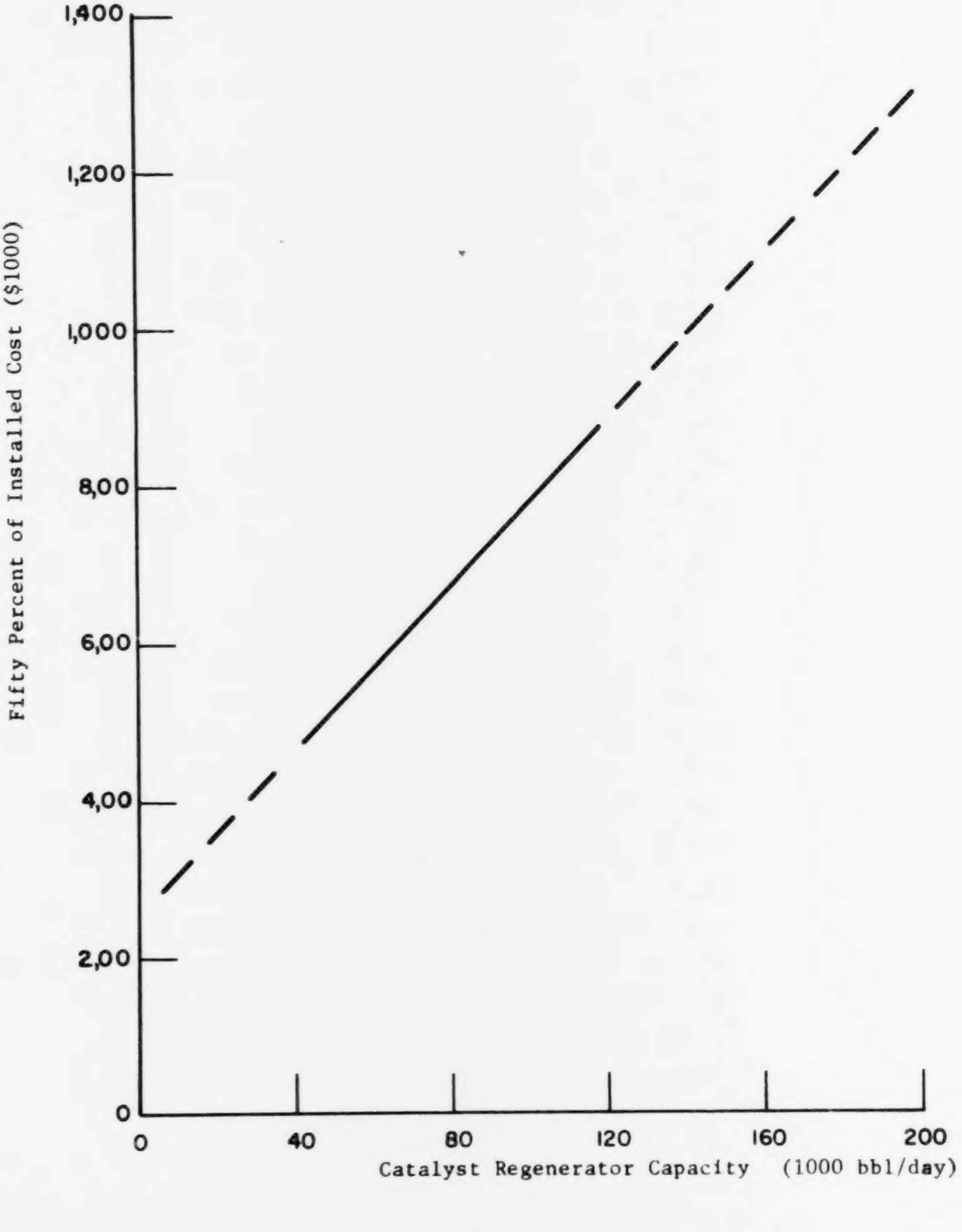

Figure 4-5. Cost of Carbon Monoxide Boilers.

Uncontrolled emissions of CO from FCC units were based on 5.6 tons of CO per 1000 barrels total feed. Uncontrolled emissions from Thermofor units were based on 1.2 tons of CO per 1000 barrels total feed. There are no significant CO or hydrocarbon emissions from Houdriflow units since they are all presently controlled. In all cases units were assumed to operate 360 days per year. CO and hydrocarbon emissions from controlled units were assumed to be zero.

Uncontrolled HC emissions from fluid units were based on 180 pounds HC per 1000 barrels total feed and those from Thermofor units were based on 57 pounds HC per 1000 barrels total feed. These figures can be converted to 32.4 and 10.3 tons HC per year per 1000 barrels total daily feed, respectively. In all cases, emissions from controlled units were assumed to be zero.

(3) Crude Oil and Gasoline Storage

The total crude oil storage capacity for each refinery was based on a 24.4-day refinery supply, and gasoline storage capacity was based on 25 days of production. A model tank size of 80 thousand barrels was selected, and the total storage capacity in each refinery was divided by 80 thousand to determine the equivalent number of model tanks. Three-fourths of these tanks were assumed already to have floating roofs and submerged fill lines; therefore, no further control was required. Since the cost for converting to a floating roof tank and installing submerged filling techniques was considerably less than installing a new tank, it was assumed that all tanks would be converted and not replaced.

Figure 4-6 presents the data used to determine tank conversion costs. Operating and maintenance costs were not determined, since these are low and are usually equal to or less than the value of the recovered gasoline and crude oil.

Emissions of hydrocarbons result from refinery activities including crude oil storage, gasoline storage, and gasoline transfer. The emission factors and percent control attainable with current technology are shown in Table 4-53.

TABLE 4-53. PETROLEUM STORAGE EMISSION FACTORS

Receptacle	Description and Controls	Emissions Breathing Loss (tons/yr/ 1000 bbls)	Working Loss (tons/1000 bbls)
Tank	Fixed roof, w/vapor recovery	-0-	-0-
	Fixed roof, w.o. vapor recovery, splash fill	$F_a = 8.5$	$F_b = 0.242$
	Fixed roof, w.o. vapor recovery, submerge fill	$F_a = 8.5$	$F_e = 0.152$
	Conservation, w/vapor recovery	-0-	-0-
	Conservation, w.o. vapor recovery	$F_d = 0.87$	-0-
Tank Vehicle	w/vapor recovery	-0-	-0-
	w.o. vapor recovery splash fill	-0-	$F_c = 0.172$
	w.o. vapor recovery submerge fill	-0-	$F_f = 0.102$

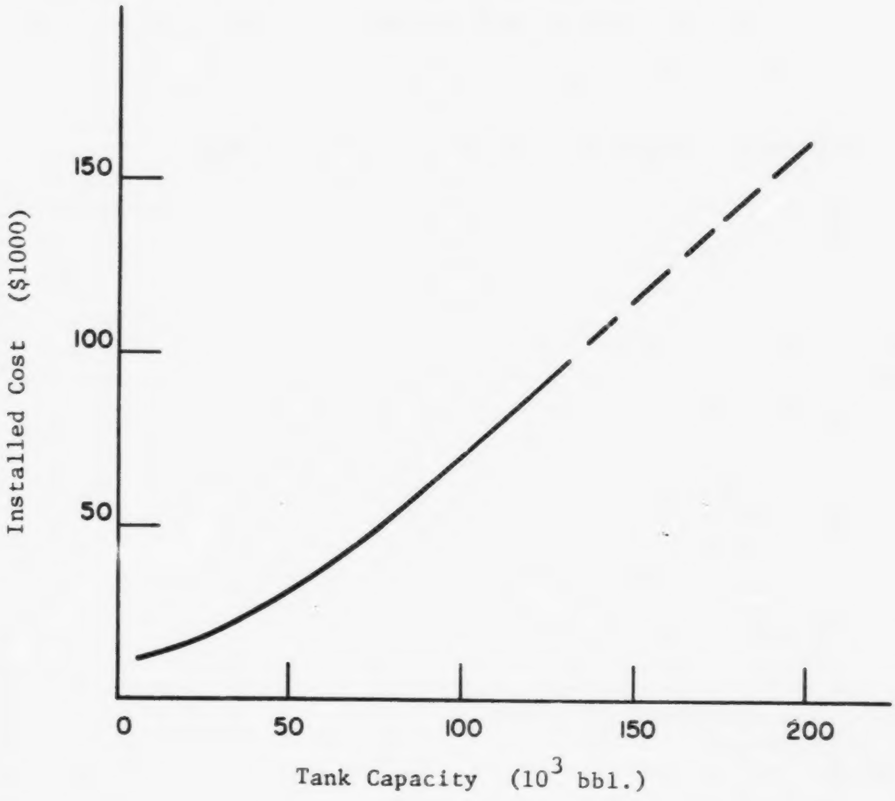

Figure 4-6. Installed Cost of Floating Roofs on Petroleum Storage Tanks.

In determining current emissions, the following assumptions were made for each refinery:

(a) Three-fourths of all crude oil storage tanks are controlled.

(b) Three-fourths of all gasoline storage tanks are controlled.

(c) One-half of all gasoline transfer operations are controlled.

(d) All gasoline produced is transferred to refinery storage tanks.

(e) Thirteen percent of gasoline is transferred to bulk plants by pipeline.

(f) All gasoline storage facilities are utilized to 60 percent of capacity.

(g) Gasoline production is 51 percent of crude oil input.

(h) All storage facilities in California are fully controlled.

The basis for calculating the control costs for gasoline storage tanks, both at refineries and at bulk terminals, is shown in Table 4-54.

Table 4-54. CONTROL COSTS FOR GASOLINE STORAGE AT BOTH REFINERIES AND BULK STORAGE LOCATIONS

Average Capacity of Establishment (Gallons)	Number of Establishments	Model Tank Size (Gallons)	Number of Model Tanks	Cost/ Tank ($1,000)	Total Control Cost ($1,000)
29,435	3643	29,435	1	12.0	9,849
52,646	5805	52,646	1	12.5	16,325
71,693	4318	71,693	1	13.0	12,636
93,292	1649	93,292	1	1 .5	5,008
134,586	1338	134,586	1	14.0	4,214
310,000	303	155,000	2	14.5	1,972
744,525	137	248,175	3	15.0	1,395
1,949,000	338	324,833	6	15.5	7,068
4,472,000	271	1,118,000	4	18.0	4,482
11,079,000	264	2,769,000	4	35.0	8,330
39,631,000	57	6,605,000	6	111.0	8,470
				Σ	79,740

3. Emissions

Both crude oil and refined products, especially gasoline, tend to give off hydrocarbon emissions due to evaporation while in storage tanks and in transfer. Other hydrocarbon emissions result from the operation of catalytic crackers.

For simplicity of analysis, all storage of refined products, whether at the refinery or at bulk terminals, has been grouped. The hydrocarbon emissions from these sources were estimated to be 1,038,000 tons in 1967, allowing for 50 percent existing control. At the same control level, these would rise to 1,349,000 tons by FY 1977. Installation of floating roofs on all uncontrolled storage tanks by FY 1977 would reduce these emissions to 296,000 tons, equal to 89 percent control.

Refinery emissions of hydrocarbons from catalytic crackers and regenerators were estimated at 153,000 tons in 1967, at 20 percent control. Industry growth would increase this to 197,000 tons by FY 1977 if control practices remained unchanged. Use of carbon monoxide-hydrocarbon boilers on crackers could effect a 95 percent control level, reducing emissions to 12,000 tons in FY 1977.

Sulfur dioxide (SO_2) emissions in refineries may occur from many sources, including internal combustion engines for compressors, boilers, catalyst regenerators, acid plants, hydrogen sulfide incinerators, and sulfur plants.

Engines and boilers are commonly fueled by sulfur-bearing gases or liquids that cause scattered, relatively dilute, sulfur dioxide emissions. Catalyst regenerators have sulfur oxides in exit gas streams, depending on the sulfur content of the coke deposited on the catalyst. Spent alkylation acid (H_2SO_4) sludge may be shipped away for regeneration, but if it is regenerated at the refinery, the emissions of sulfur oxides should be similar to those for other nonsulfur-burning acid plants. Hydrogen sulfide (H_2S) incineration, at refineries producing H_2S not used for acid sludge regeneration or sulfur plant feed, is a large concentrated source of SO_2 emissions; when sulfur plants are used on the H_2S stream (in place of incineration), they are strong sources of SO_2 emissions.

The primary source of SO_2 in most refineries results from processing the H_2S-rich stream generated from various desulfurization and sweetening processes. The H_2S stream is most commonly produced in the regeneration of spent amine scrubbing liquors used to sweeten product, process, or exhaust streams. The stream may be incinerated, sent to a spent acid regeneration plant, or sent to a sulfur recovery plant. All three processes result in significant emissions of sulfur oxides. Incineration of hydrogen sulfide to sulfur dioxide is normally controlled by recovery as sulfuric acid; these and spent-acid plant emissions are included in Section P on sulfuric acid. Sulfur plants and their tail gas streams are considered below. The H_2S-rich stream is amenable to partial recovery by conventional Claus sulfur plants.

Hydrogen sulfide emissions in refineries are best controlled by use of sulfur recovery plants. The available data indicate that many of the refineries had sulfur plants in 1967 and that overall these provided control of 37 percent of emissions. Thus, the plants emitted 2,310,000 tons of sulfur oxides per year, and it is estimated that industry growth would increase this to 3,010,000 tons by FY 1977 with the same sulfur contents and level of control. Installation of sulfur plants and tail gas cleaners on all refineries could reduce the FY 1977 emissions. of sulfur oxides from these sources to 20,800 tons per year, which is a 99.5 percent level of control. There are additional sulfur oxide emissions that result from operations involving the combustion of natural gas and/or fuel oils for process purposes. These are not generally amenable to control.

Regeneration of the catalysts used in catalytic cracking units results in emission of catalyst fines (particulates) and carbon monoxide. An estimated 240 pounds of particulates per thousand barrels of total feed are emitted from fluid catalytic cracking unit regenerators in the absence of air pollution control equipment, and an estimated 12.5 pounds per thousand barrels of total feed from thermofor and houdriflow unit regenerators. Installation of electrostatic precipitators provides the maximum control now available, and should easily meet the assumed process weight rate standard. In 1967, the regenerators in the refineries emitted an estimated 185,000 tons of particulates at an average industry control level of 20 percent. Normal growth of the industry would increase this to 241,000 tons by FY 1977. Installation of precipitators in all plants would reduce FY 1977 emissions to 98,000 tons, at 67 percent control.

Carbon monoxide in the exit gas of regenerators was controlled by carbon monoxide boilers in many refineries in 1967, but there were still as estimated 9,300,000 tons emitted in that year (20 percent controlled). The carbon monoxide boiler burns the carbon monoxide into carbon dioxide (and also burns hydrocarbon emissions from the catalytic cracking unit) and provides a substantial source of heat for process use in addition to controlling pollution. Installed in all the subject refineries, they would control all but a negligible amount of carbon monoxide and hydrocarbon emissions from the cracking process. Without this control, it is estimated that carbon monoxide emissions would increase to 12,100,000 tons per year in FY 1977.

3. Scope and Limitations of Analysis

Analysis of refinery emissions and control equipment was, in almost all cases, based on data for each refinery involved. Control costs have been estimated on a less rigorous basis, as indicated below, by two model firms, but are representative of actual cost expectations. Because the total annualized cost is not estimated to be large enough to influence prices, no analysis of market patterns is presented.

4. Industry Structure

Nearly all bulk storage plants are owned by producers of petroleum products. Although approximately 256 plants are listed as petroleum refiners, the industry is concentrated in 30 to 35 firms; of these, 16 are fully integrated international corporations making up the so-called "large majors" of the industry, another eight firms are fully integrated "small majors," and the remainder are somewhat smaller and either not fully integrated or operative in a limited market. Salient statistics concerning refineries and bulk storage plants are given in Table 4-55.

Petroleum is an oligopolistic industry characterized by sharp retail competition that usually concentrates on competitive advertising at the retail level, but it experiences frequent price wars as well. In its purchases of crude oil from independent producers, it is much less likely to compete on price.

The entire industry is subject to foreign competition, but at present this is minimized through quotas under the oil import program.

The effect of the quota system is to set a base price higher than would probably be set, were unlimited imports permitted.

TABLE 4-55. THE PETROLEUM REFINING AND STORAGE INDUSTRY, 1967

Refining Plants				Bulk Storage Plants			
No.	Capacity	Production	Value of Shipment (billions)	No.	Capacity	Production	Value of Shipment (billions)
	million bbl				million bbl		
256	4,210	3,580	$ 20.29	18,123	214	1,873	$ 22.50

5. Economic Impact of Control Costs

a. Cost Factors

Floating roofs for refinery tanks are estimated to require an investment ranging from $12,000 to $111,000 each, with most costing less than $18,000. Since this control reduces vapor loss of a valuable product by more than 90 percent, there is a saving that more than offsets the total operating and maintenance costs. The impact of the annualized capitalization costs is minimal.

Sulfur recovery plants vary in cost depending on size, which is a function of the daily quantity and the sulfur content of crude oil refined. For those refineries not listed as having sulfur recovery plants in 1967, this cost was calculated on the basis of plant size necessary for the listed capacity of the refinery and on its estimated sulfur oxide emissions. Sulfur recovery plants of 4-ton-per-day capacity or larger were considered economically feasible; these require investments ranging from slightly over $100,000 for 4-ton capacity to $630,000 at 100 tons. Annual costs were considered to be offset by the value of sulfur produced. The value of sulfur is, of course, subject to change if large additional supplies are marketed. However, since it appears that the sulfur recovery plants now in use at petroleum refineries are operated at or above the break-even point, it is assumed for this analysis that additional plants could produce revenues at least equal to annual costs.

The tail gas from the sulfur plant contains some sulfur oxide which must be removed by a cleaner. For the average sulfur plant this is estimated to require an investment of $370,000 and annual cost of $103,600.

Electrostatic precipitators for control of particulate emissions from catalyst regenerators on fluid catalytic cracking units vary in cost depending on size. It is estimated that the average refinery would invest approximately $642,000 for each precipitator. The total annualized cost per precipitator is estimated to average $128,000.

Carbon monoxide boilers to control carbon monoxide and hydrocarbon emissions from catalyst regenerators were estimated on the basis of the heat content of the gas stream for each affected refinery and the price of boilers. The average investment required would be approximately $3 million per boiler, of which 50 percent is charged to air pollution control, since the steam generated is usable in the normal operating processes of the refinery. Similarly, the operating and maintenance costs may properly be considered production cost rather than cost of pollution control.

b. Aggregate Industry Costs

For the petroleum industry as a whole, installation of the controls specified in this analysis would require, by the end of FY 1977, a total investment of $378 million. Given the assumptions stated above, annual cost to the industry would, however, amount to only an estimated $73.3 million per year upon completion of installation of controls in FY 1977.

c. Two Model Firms as Examples of Economic Impact of Control Costs

Two hypothetical petroleum companies are used to illustrate the impact of the investment requirements and the annual costs explained above.

Description of Model Firm A

A fully integrated national producer, operating 10 refineries

Total crude oil refining capacity: 877,000 b/cd.
Gasoline production of crude oil: 52.6 %
Capacity utilization: 88.6 %

Gross revenue, $7,860 million
Net income, 640 million

Costs for Air Pollution Control Equipment (Model Firm A)

Equipment	No.	Investment	Annual Cost
Carbon monoxide boiler	4	$7,200,000	$ 720,000
Sulfur plant	12	7,560,000	756,000
Tail gas cleaner	20	9,800,000	2,740,000
Electrostatic precipitator	9	6,350,000	1,270,000
Storage tank (crude) roofs	40	530,000	53,000
Storage tank (gasoline) roofs	441	7,100,000	710,000
TOTAL		$38,540,000	$6,249,000

Description of Model Firm B

A small independent partially integrated firm, operating one refinery

Total crude oil refining capacity: 53,000 b/cd.
Gasoline production of crude oil: 51 %
Capacity utilization: 85 %

Gross revenue, $57 million
Net income, 11 million

Costs for Air Pollution Control Equipment (Model Firm B)

Equipment	No.	Investment	Annual Cost
Carbon monoxide boiler	1	$1,500,000	$ 150,000
Sulfur plant	2	960,000	96,000
Tail gas cleaner	2	740,000	207,000
Electrostatic precipitator	1	550,000	110,000
Storage tank (crude) roofs	3	40,000	4,000
Storage tank (gasoline) roofs	28	453,000	45,000
TOTAL		$4,243,000	$ 612,600

d. Impact on the Industry

If the total annualized cost of air pollution control for the petroleum industry, as estimated here, were added to the price of gasoline production projected for FY 1977, it would increase that price by approximately $0.022 per barrel($73.3 million ÷ 3,300 million barrels). Costs of this magnitude are not likely to affect the final prices of petroleum products or to reduce the profits of the refiners.

More significant is the magnitude of the investment. It appears that this industry will be required to invest $378 million by FY 1977. At the same time, it appears that there will be a substantial excess of demand for petroleum products, so producers will be under pressure to expand their exploration expenditures and to increase production capacities. Some small companies may find it difficult to raise the capital essential to their total investment program. In general, total control investment costs probably do not, at the most, exceed 10 percent of any company's annual investment outlay, and are generally much less. Considering the general pattern of low debt-to-equity ratios in this industry and that the return on investment is higher than that of the average industrial firm, the costs indicated are not likely to threaten the financial stability of the industry.

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L. Phosphate Industry

1. Introduction

a. Nature of Products and Processes

Phosphate rock is processed into many products used in the United States. Chiefly, these are agricultural fertilizers (75 percent), animal feed supplements, elemental phosphorous, and phosphoric acid.

Complete or balanced fertilizers involve producing P_2O_5 ("phosphate") from phosphate rock and mixing this chemically and/or mechanically with nitrogen and potassium nutrients. Plant foods are produced in various NPK (nitrogen, phosphorus, potassium) grades to fit varying soil requirements.

The manufacture of the phosphate for fertilizers begins with the preparation of rock for processing. Ground rock is treated with sulfuric acid to produce either normal superphosphate fertilizer (20 percent P_2O_5) or wet process phosphoric acid. This acid intermediate (about 54 percent P_2O_5) may be used to produce diammonium phosphate (18 percent nitrogen and 46 percent P_2O_5) or triple superphosphate (46 percent P_2O_5). Superphosphoric acid (about 70 percent P_2O_5) is produced by dehydration of wet process phosphoric acid and used in the preparation of mixed liquid fertilizers for direct application to the soil.

b. Emissions and Costs of Control

Dusts, acid mists, sulfur dioxide, fluorides (gaseous and particulate), and ammonia are emitted from various processes in the phosphate fertilizer industry. Dusts are emitted from drying and grinding of phosphate rock, calcination, drying and cooling in the granulation process (the major source), and conveying, bagging, and other handling operations. Sulfur dioxide is emitted from the sulfuric acid plants owned by some major phosphate processors that produce wet process phosphoric acid. (Sulfuric acid production is discussed in detail under Section P; the control costs described in that section have their major economic impact on the fertilizer industry.) Although fluorides and ammonia are emitted, they are not considered in this study; primary producers of concentrated phosphates have been affected by state statutes limiting fluoride emissions to such an extent that they have installed the most stringent controls in the industry.

For 1967, the phosphate fertilizer industry emitted about 260,000 tons of particulates, with an overall control level of 89 percent. Of this amount, 170,000 tons came from drying and cooling steps following granulation, and another 45,000 tons came from phosphate rock preparation. Growth of demand for phosphate products in fertilizers is estimated to be 4.2 percent annually. Extrapolation of industry trends show that emission of particulates would increase at a lower rate than production due to shifts toward liquid fertilizers and diammonium phosphate production and away from normal superphosphate, triple superphosphate, and the ammoniator-granulation processes. Due to implementation of the Act and these changing industry trends, the particulates loading should level out at about 160,000 tons in 1977. Without the Act, the emissions would probably increase to 350,000 tons by 1977. To control drying and cooling processes in granulation plants, the phosphate industry will have to invest about $31 million for additional control equipment and spend $15 million annually for full implementation of the assumed emission controls.

c. Scope and Limitations of Analysis

This analysis was based on data available from government, trade, and financial reporting services. Financial data are available only for a limited number of firms--mostly conglomerates deriving major portions of their revenues from nonfertilizer-related businesses. Data were sparse for firms which rely heavily on the fertilizer business. Without more detailed information, estimation of revenues, costs, profits, and taxes attributable to fertilizer was not possible. For this reason, the relationships assumed for the financial variables depict the general condition of the industry, and do not relate to any specific enterprises.

2. Engineering Basis of Analysis

Pollutants from drying and cooling steps during granulation are emitted from three characteristically different plants--triple superphosphate, concentrated ammonium superphosphates (such as diammonium superphosphate), and mixed fertilizer (NPK) products. Based on available data, granulation in 1967 contributed 170,000 tons of particulates, or 65 percent, of the total emissions from the phosphatic fertilizer industry. The emission factors and average industry emissions produced are as follows:

Process Step	Pollutants Generated, Lbs Per Ton Product	Actual Emissions, Lbs Per Ton Product
(a) Dryer	105	10.5
(b) Cooler	90	9.0

Source: Midwest Research Institute

Single-size model plants were developed for three plant types to cover all aspects of chemical fertilizer product (bulk blending excluded). The concentrated phosphates, with and without ammoniation, are represented by the triple superphosphate and diammonium phosphate models. The NPK model includes normal superphosphate, as well as processors of mixed acids, ammonia, potash, and other nutrients. Emission factors, rates of emission, and allowable emissions under the assumed process weight rate standard are shown in Table 4-56 for the three models.

Investment costs for the model plants were built from cost data for stainless steel venturi scrubbers shown in Figures 4-7 and 4-8. Investments were corrected to 1970 dollars. Operating costs, mostly chargeable to energy consumption for fan pressure drops in the range of 20 to 35 inches water column, were developed from the curves in Figure 4-9. Annual maintenance costs were estimated at five percent of original investments. All cost related data per model plant are presented in Table 4-58.

The total population of granulation plants is described by the size distribution shown in Table 4-57. There were some 350 of these plants in 1967. Generally, the smaller plants are those that may be considered NPK plants. The large-sized plants, over 100,000 tons per year, are the concentrated producers, as discussed earlier. Based on the size distribution presented here and the three models shown in Table 4-58, aggregate costs were calculated for the industry as it existed in 1967. To estimate the growth through 1977, it was assumed that only diammonium phosphate plants would be built as new sources. A growth rate of 4.2 percent in ammonium phosphates production was used. Fifteen such new plants were used as new sources in the estimation of total costs through 1977.

TABLE 4-56. MODEL PLANT EMISSION DATA FOR THE PHOSPHATE INDUSTRY

Process Variables	TYPE OF GRANULATION PLANT		
	Triple Superphosphate	Diammonium Phosphate	NPK
Production Rate, tons per hour	40	25	17.5
Process Weight Rate, tons per hour	280	175	123
Emission Factor,[1/] lbs per ton product	120	300	340
Actual Emissions,[1/] lbs per ton product	6.0	15.0	17.0
Allowable Emissions,[1/] lbs per ton product	1.0	1.4	2.1

[1/] Combined Dryer and Cooler Effluents

Source: Chemical Construction Corporation

TABLE 4-57. DISTRIBUTION OF PLANT CAPACITY FOR GRANULATION PLANTS

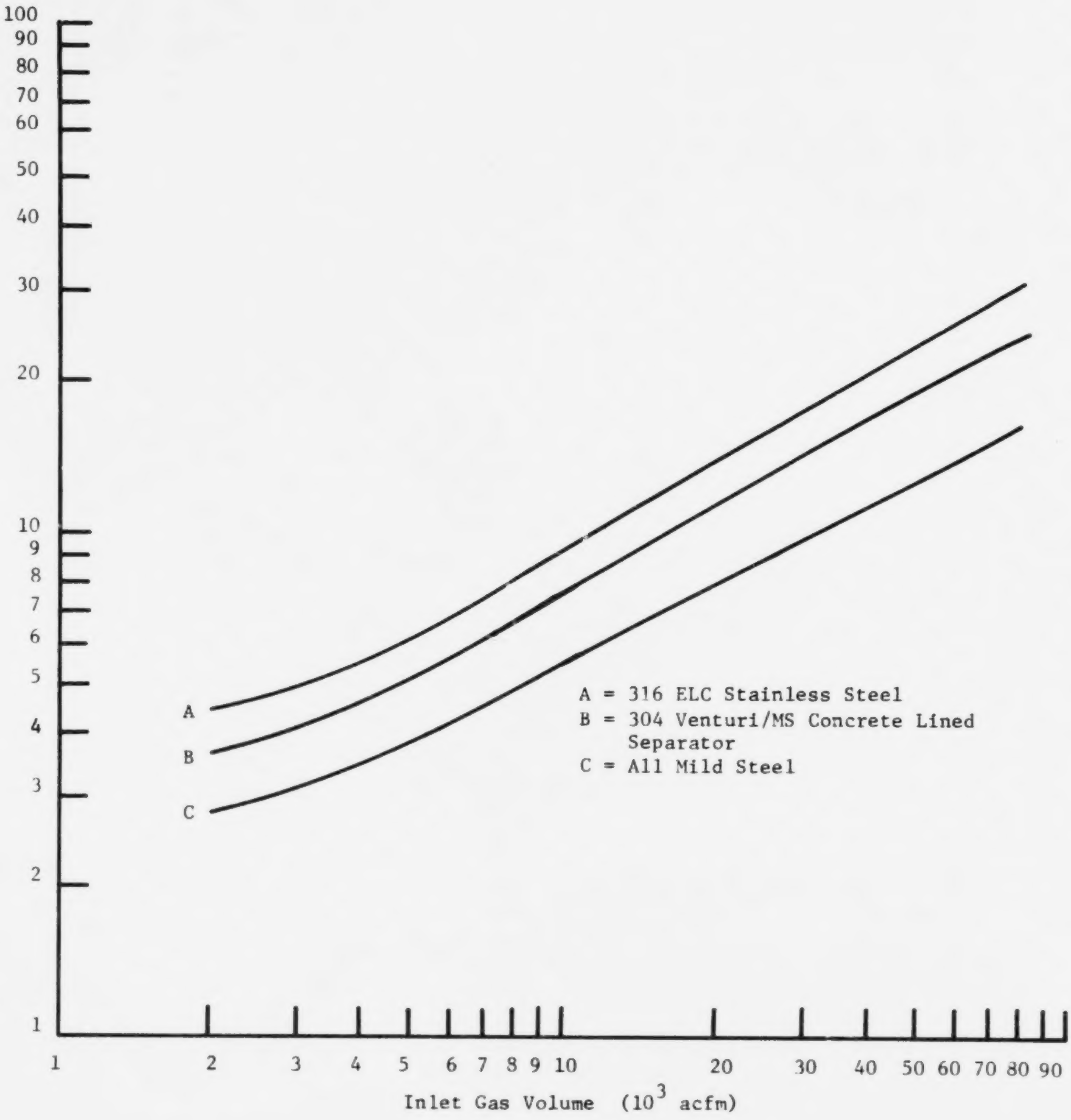
Plant Capacity, Ton Per Year	No. of Plants[1/]
0-10,000	5
11-20,000	19
21-30,000	20
31-40,000	18
41-50,000	9
51-60,000	18
61-70,000	8
71-80,000	3
81-90,000	2
91-100,000	3
101-110,000	7
125,000	2
300,000	1
	115

[1/] Plants with reported capacity only.

Source: National Emission Standards Study, Report to the U. S. Congress in Compliance with P. L. 90-148, by Secretary of U. S. Department of Health, Education, and Welfare, March 1970.

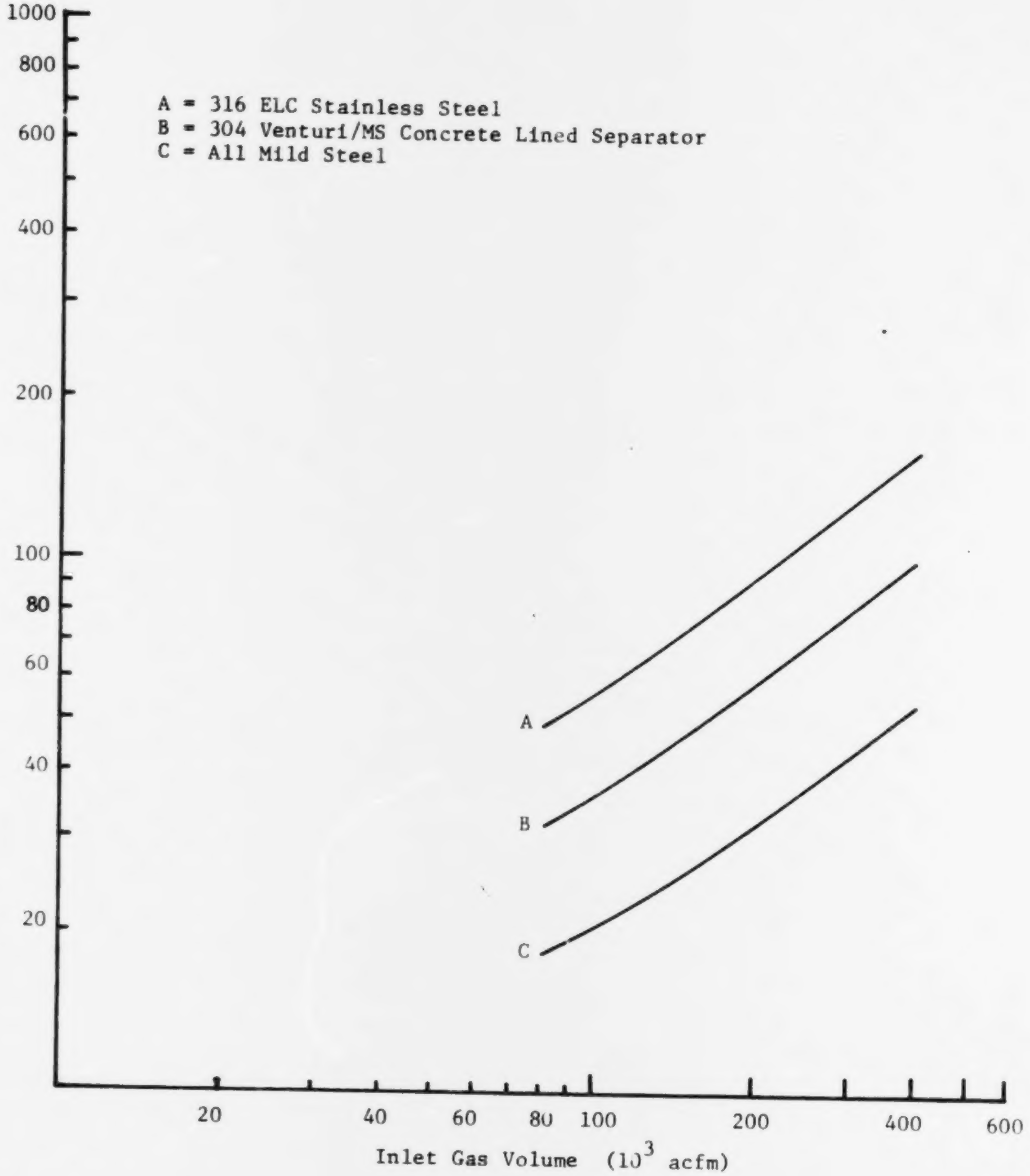
TABLE 4-58. MODEL FERTILIZER PLANT PRODUCTION DATA AND CONTROL REQUIREMENTS

ITEM	TYPE OF GRANULATION PLANT		
	Triple Superphosphate	Diammonium Phosphate	NPK
Type of Product	0-48-0	18-46-0	13-13-13
Production Rate, Tons Per Hour	40	25	17.5
Gas Volumes, ACFM			
(a) Dryer	120,000	36,000	12,000
(b) Cooler	---	27,000	18,000
(c) Screens	65,000	---	
Purchase Cost	$100,000	$30,000	$20,000
Installed Cost	$390,000	$125,000	$75,000
Annual Cost	$177,000	$64,000	$34,000
Hours of Operation (per year)	4800	4800	2900
Fertilizer Production, tons per year	190,000	120,000	50,000
Control Cost, per ton product	$0.93	$0.53	$0.68



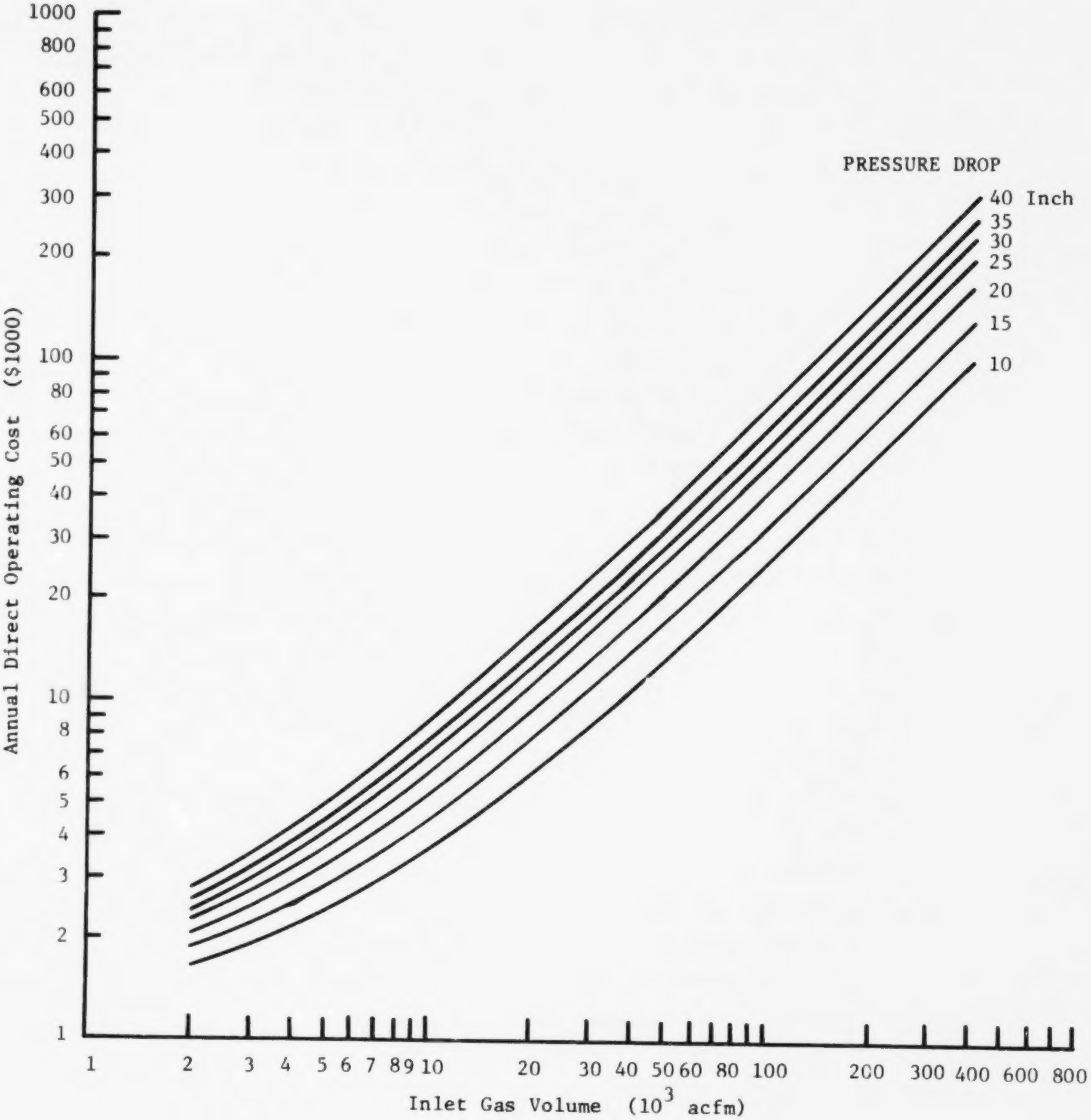
Source: Poly Con Corporation.

Figure 4-7. Equipment Cost for Venturi Scrubbers.



Source: Poly Con Corporation.

Figure 4-8. Equipment Cost for Venturi Scrubber.



Source: Poly Con Corporation.

Figure 4-9. Annual Direct Operating Cost for Venturi Scrubber.

3. Industry Structure

a. Characteristics of the Firms

The phosphate processing industry included approximately 60 firms in the United States in 1967. These firms owned 22 triple superphosphate plants, 54 ammonium phosphate plants, and 350 granulated NPK plants. In addition, there are some 3,000 bulk blend fertilizer plants, many of which were owned by the same firms operating the chemical processing plants subject to air pollution control. Most of the firms engaged in fertilizer production are well established in other operations, such as petroleum products, gas production, nonphosphate-related chemicals, animal feeds and supplements, meat packing, and diverse agricultural supplies such as rope, wire, machinery, machinery parts, and hardware.

The trend of the phosphate industry in recent years has been toward production of concentrated phosphates, triple superphosphate, and diammonium phosphate--which can be shipped greater distances economically--and away from production of normal superphosphate, which cannot. Plant capacities of the concentrated phosphates are on the order of 300,000 tons per year. Many of the NPK plants which operate with normal superphosphate production have an annual capacity of about 30,000 tons. These NPK plants, located in farming areas all over the country, generally operate at full capacity only 4 to 6 months per year, due to the seasonal nature of the business.

b. Operating Characteristics

Excess capacity exists for all segments of phosphate processing. Production of phosphoric acid, which is an important intermediate for phosphate fertilizers, is currently running at about 70 percent of capacity. Ammonium phosphates and triple superphosphate are nearly the same. Major producers, most of whom own phosphate rock reserves, manufacture wet process phosphoric acid and concentrate phosphates near their mine sources. These phosphates, approximately 46 percent in P_2O_5 content, effect savings over lower analysis products in transportation costs to far distant markets.

Useful P_2O_5 is extracted from phosphate rock with sulfuric acid. Approximately one ton of sulfuric acid is needed to produce one ton of fertilizer purchased by the farmer, such as 5-10-10 (5 percent nitrogen, 10 percent P_2O_5, 10 percent potassium oxide). There is no economically priced substitute for sulfuric acid.

4. Market

a. Distribution

Most of the phosphate fertilizers are consumed in the North Central States, primarily for corn and wheat grain production. The P_2O_5 content for fertilizers consumed in this region is above the national average. Most of the normal superphosphate (low analysis P_2O_5) is consumed in the southeast. An advantage of normal superphosphate over its higher analysis rivals is its high sulfur content, a necessity for tobacco soils.

Operations of NPK granulation plants are especially designed to chemically mix fertilizer materials, mainly for local use. They purchase phosphoric acid, run-of-pile triple superphosphate, phosphate rock, run-of-pile normal superphosphate, ammonia, potash, and sulfuric acid and various other raw materials. Their product is a highly water soluble, balanced plant food of guaranteed analysis in nitrogen, phosphate, and potash ingredients. These NPK plants serve as distributors of products from the primary phosphate producers.

Another group of distributors is the bulk blenders. Bulk blender operations mechanically mix granulated products, whereas NPK plants chemically mix and granulate. They, like NPK plants, offer special recipes mixed for the individual farmer and thus guarantee a complete plant food in terms of nitrogen, phosphate, and potash.

b. Competition

The fertilizer industry markets some thousand grades of products throughout the country. Distributors with bulk blending operations will favorably compete with NPK producers because of the low investment required for blending equipment, low operating cost of bulk blenders, and the ability to offer both liquid and dry fertilizers. The NPK producer could do the same but would still have heavy fixed costs in his chemical dry-mix plant.

From the primary producer's view, competition is severe as the result of overexpansion in phosphoric acid and concentrated phosphate capacities. Only those firms with both large processing facilities and vertical integration with ownership of rock and/or sulfur resources can have a price advantage. The cooperatives enjoy a special situation--they have a captive market and they have certain tax advantages. In the late 1960's, exports have served as an outlet for surplus production: in 1968, exports accounted for 30 percent of triple superphosphate produced and 32 percent for ammoniated phosphates.

5. Trends

a. Capacity and Production

Since 1965, the phosphate industry has been plagued with overcapacity. Growth in production between 1960 and 1965 was substantial for the concentrated products--notably, wet phosphoric acid, triple superphosphate, and ammoniated phosphate. (Normal superphosphate sharply declined during the same period). Growth was stimulated by advances in wet phosphoric acid technology and by government restriction on land under cultivation. The restriction on cultivation sharply increased demand for concentrated nutrients for increased crop yields. Indications of overcapacity in wet phosphoric acid are shown in the following data:

Year	Production (1000 Tons P_2O_5)	Operating Ratio (Percent)	Capacity (1000 Tons P_2O_5)
1961	1,213	61.0	1,981
1965	2,682	52.0	5,148
1969	3,067	60.5	5,979
1970	4,165	69.5	5,979

Apparently at the expense of the ammoniated phosphates, triple superphosphate, which had grown rapidly through the early 1960's, topped out in 1965 and declined through 1970. Its use in mixed fertilizers has sharply declined, but by bulk blenders use is still rising. The rise in ammoniated phosphates has been good for both NPK and bulk blenders since both groups deal in this product. Bulk blenders seem to be gaining in their share of the markets. Statistics for 2 comparable years show that bulk blenders rose in number from 200 in 1950 to 4,140 in 1968.

Because of the low price of ammonia and improvement of phosphoric acid technology, ammoniation of phosphates will continue to increase for some time in the future. As a partial supplier of available nitrogen, diammonium phosphate will cut into nitric acid production for nitrate fertilizer, discussed elsewhere in this report.

b. Price, Sales, and Profits

Prices have declined for all phosphate fertilizers during the 1960's. Diammonium phosphate fell from $120 per ton in 1962 to $94 in 1970; triple superphosphate, from $84 per ton in 1967 to $75 in 1970; phosphoric acid, from $79 per ton in 1963 to $55.50 in 1970. Price declines, also present in nitrogen and potash, have obliterated profits. According to the Fertilizer Institute, basic fertilizer producers (excluding distributors) suffered losses from 1967 through 1969. In 1970, the industry finally turned the corner to making a profit. A comparison of financial tacts for 1969 and 1970 from the Institute is shown in Table 4-59.

TABLE 4-59, FERTILIZER INDUSTRY STATISTICS

	1969	1970
Net Sales (millions)	$1,430	$1,680
Gross Profit (millions)	175	308
Selling, general and administrative expenses (millions)	253	317
Other Income (millions)	7	24
Net earnings before interest and taxes (millions)	-70	15
as percentage of sales	-4.3%	0.8%
Average retail price per ton	53.26	56.25
Average time between sale and payment (days)	116	119

6. Economic Impact of Control Costs

a. Impact on a Plant

To show the impact of air pollution control costs, a model plant approach was used to typify operating patterns of two competitive situations--namely, an NPK plant and a diammonium phosphate plant.

The latter sells its product directly to a distributor (fertilizer, feed, and grain dealer) or to a bulk blender. The former may be its own distributor. The basic model plant descriptions are shown in Table 4-60, and abbreviated income statements are shown in Table 4-61.

The magnitude of air pollution control costs is shown in the income statements for two model plants. Both plants are assumed to purchase necessary raw and intermediate materials from outside sources. The NPK plant may be representative of many granulation plants--granulating either run-of-pile normal or triple superphosphate. The diammonium phosphate model plant may typify an efficient, large plant; however, integrated firms with corporate reserves of raw materials would

TABLE 4-60. BASIC DESCRIPTION, FERTILIZER PLANT

	Plant Type	
	DORR-OLIVER	TVA
Product	12-12-12	16-48-0
Capacity, Tons/hour	17.5	25
Construction Cost, without Dust Control 1966*	$1,700,000	$1,950,000
Control Investment	$ 75,000	$ 125,000
Production, Tons/year	$ 50,000	120,000
Average Price to Distributor, 1970	$ 58.70	$ 86.70
Farmer's Price, 1970	$ 66.00	$ 94.00

*Excludes land, offsite facilities, and railroad siding

TABLE 4-61. ANNUAL INCOME STATEMENT, FERTILIZER PLANT
(Thousands of Dollars)

	NPK		Diammonium Phosphate	
	Without Control	With Control	Without Control	With Control
Sales	2,935	2,935	10,400	10,400
Cost of Goods Sold	2,910	2,910	9,985	9,985
Added Control Cost	0	34	0	64
Net Income Before Tax	25	-9	415	351
Income Tax	12.5	0	207	175
Net Earnings	12.5	-9	208	176
Cash Flow	182.5	168.5	403	383.5

show better profitability than the model plant.

c. Impact on the Firm

A few large firms, possibly a dozen, produce the majority of concentrated phosphate fertilizers in this industry. These firms are usually involved in natural resource exploration and development, in support of their phosphate production. Depletion allowances for the resources used provide a source of funds over and above production activities. Their need to raise capital for emission control equipment does not pose a serious problem.

The smaller firms engaged heavily in the mixed fertilizer business may be seriously hampered. Much of the older, inefficient equipment will be shut down. (This trend was noted in recent experience in the questionnaire survey of the phosphate industry.) NPK plants in general will face the brunt of the economic impact of air pollution control requirements for the industry. Whether or not they continue operations will depend on the financial resources of the firms owning the plants. Many of these firms, including regional cooperatives, are involved in other agricultural operations such as marketing of commodities and distribution of agricultural goods. They usually operate on a county or statewide basis and control prices in the areas they serve. Their financial positions would allow them to support investments for emission control for existing operations or to convert existing facilities to bulk blending, which is not a significant pollution source.

d. Demand Elasticity and Cost Shifting

The aggregate demand for phosphate fertilizers appears bright for the future. As population increases, acreage for cultivation will decrease as urbanization takes up much of the land suited for high crop yields; remaining usable land will require larger nutrient additions. Thus, because no substitutes exist for readily available, water-soluble phosphate, nitrogen, and potash, the future of the mixed fertilizer business looks good.

Air pollution control costs will be shifted to the farmer to the extent reflected in the full increment for diammonium phosphate--namely, $0.53 per ton of fertilizer or the equivalent of $0.008 per unit of nutrient (1 unit equals 20 lbs.). This will result in a price increase of only 0.5 percent for average commercial fertilizer products. Triple superphosphate and granulation operations will have to absorb at least half of the added cost of control due to the capacity growth of diammonium phosphate as new diammonium phosphate plants replace triple and normal superphosphate plants.

e. Effect on the Industry

Normal superphosphate is declining significantly. Since the cost of pollution control is minimized by incorporating it into a concentrated product, diammonium phosphate, economic benefits should accrue to the bulk blenders and eventually the farmer. This will reinforce the present competitive advantage bulk blending has over granulating NPK. According to the Bureau of Census manufacturers' data for 1967, the average price of mixed goods sold by bulk blenders was $54.20 per ton. Mixed goods produced by NPK plants sold for $55.19 per ton.

Prices of products rose in 1970 for the first time in 4 years; thus, the overcapacity situation in the industry is improving, although profits may be slow in following. As long as supplies of raw materials remain in abundance, pollution control should not restrict the industry from regaining former profitability.

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M. Primary Aluminum

1. Introduction

a. Nature of Product and Process

Aluminum does not occur naturally in metallic form, but as an oxide in a wide variety of ores. Although it can be produced from almost any ore, bauxite is most economical, and virtually all aluminum is produced from this source. The ore is processed to remove impurities and chemically combined with water, leaving alumina (aluminum oxide), from which aluminum is produced by an electrolytic process.

Metallic aluminum is produced by passing an electric current through a molten bath of alumina dissolved in cryolite (Na_3AlF_6) which serves as the electrolyte. This is accomplished in a large carbon-lined steel pot holding the alumina solution, with carbon anodes suspended from above and extending down into the solution. The carbon combines with the oxygen in the alumina, gradually consuming the anode. The aluminum gathers at the bottom of the pot and is periodically syphoned off. The pots are run continuously over long periods of time with alumina added as necessary to maintain the necessary solution and the anodes gradually lowered into the bath to maintain the required position.

Three types of pots are employed, distinguished by the type of anode and the location of the spikes through which the current is fed to the pot. Prebaked systems use anodes that are carbon blocks separately formed and baked before use. In the Soderberg system, an unbaked carbon paste is fed into a casing in which it is baked by the heat of the process as it is lowered, with additional paste feeding in constantly from above. Two types of Soderberg pots are used: horizontal spike, with the spikes on the side of the pot, and vertical spike, with the spikes on the top.

All three types of pots are currently in use in the industry. Their differences are noted here because they directly affect the rate of pollutant emissions and the efficiency and cost of control. The pots are operated in large cell rooms containing lines of up to 180 pots arranged in a row or loop to provide close spacing for economical electrical connections.

2. Engineering Basis of the Analysis

On the basis of the process weight rate limitation in Appendix I, required control efficiencies for the three cell types were calculated. These are shown in Table 4-62. On the basis of the latest information provided by EPA (research under progress by Singmaster and Breyer), the control system chosen to provide the above control levels was selected and is shown in Table 4-63. It should be noted that although fluoride control requirements were not considered explicitly, the choice of control systems was made to provide partial control of fluorides.

TABLE 4-62. REQUIRED CONTROL EFFICIENCY

	Control Efficiencies Required (percent)		
Plant Capacity (1,000 tons/year)	Prebaked	Vertical Spike Soderberg (VSS)	Horizontal Spike Soderberg (HSS)
50	94.4	97.6	95.9
100	95.6	98.3	97.0
150	97.1	98.8	98.0
200	97.8	99.1	98.5
250	98.3	99.3	98.8

TABLE 4-63. CONTROL SYSTEMS FOR ALUMINUM REDUCTION CELL POTROOMS

Cell Type	Primary Control Systems	Secondary Control Systems
Prebaked	Primary Collection Coated Filter Dry Scrubber	Crossflow Packed-bed Water Treatment
VSS	Primary Collection Dry ESP Crossflow Packed-bed Water Treatment	As above
HSS	Primary Collection Wet ESP Crossflow Packed-bed Water Treatment	As above

Based upon Singmaster and Breyer's analysis, unit cost estimates for these systems were developed and are shown in Table 4-64.

TABLE 4-64. - UNITS COSTS FOR COMPLETE CONTROL SYSTEM
(Dollars per Ton of Aluminum)

Cost Item	Prebaked	Vertical Spike Soderberg	Horizontal Spike Soderberg
Capital Cost	$125.47	$154.06	$274.36
Total Annual Cost	41.12	49.78	86.95
Net Annual Cost[1]	30.84	48.94	86.95

[1] Allows for chemical recovery.

3. Emissions, Controls, and Cost of Control

Particulates are the only emissions considered in this study. Particulate emissions from the potlines in primary aluminum plants in 1967, with 73 percent control, were 31,800 tons. At the same level of controls, there would be 48,700 tons of particulates emitted by FY 1977.

The emission control systems required for even close approach to the applicable standard are very complex because of the extremely fine nature of the particulates and the large gas volumes which must be handled. Each pot must be hooded and vented to a primary collection system to capture as much of the emission as possible with minimum gas flow. The proportions of particulates captured by the best possible hooding systems are shown in Table 4-65 for each pot type. Also shown in the table are the overall control efficiencies attainable for each pot type. These provide an average control of 97.2 percent for the industry. To meet the applicable standard, each plant should achieve an overall removal efficiency of approximately 98 percent. As the table shows, only newer prebaked plants will do so.

The type of pot in use determines what type of primary control system is required; these systems and the associated removal efficiencies, are listed in Table 4-66. For the remaining emissions the pot room itself acts as a hood and is vented to a secondary control system. All pot rooms require use of crossflow packed-bed wet scrubbers with appropriate water treatment, achieving a 90 percent removal of entrained particulates.

Costs of control for Soderberg pots are significantly higher, even at the lower overall efficiencies shown in Table 4-66, because the hooding is relatively inefficient. In addition, gaseous hydrocarbons from the anode slurry are driven off as the anode bakes during pot operation. These hydrocarbons must be flared to avoid fouling the emission control systems, thereby greatly increasing gas handling problems. These hydrocarbons also affect the fluorides in the gas stream; only fluorides recovered from prebaked pots are reusable. Cost savings from reuse of these fluorides are included in the control costs presented below.

TABLE 4-65. PARTICULATE EMISSION CAPTURE BY CELL HOODS

Pot Type	Amount of particulates captured by best available hooding (%)	Overall control efficiency attainable (%) *
New prebaked	95	98.2
Older prebaked	79	97.1
Vertical spike Soderberg	50	94.5
Horizontal spike Soderberg	80	97.2

*Only systems on new prebaked potlines are capable of meeting the process weight rate standard.

TABLE 4-66. PRIMARY (CELL HOOD) EMISSION CONTROL SYSTEMS

Pot Type	Control Systems	Removal Efficiency (%)
Prebaked	Fluidized-bed dry scrubber	99
Vertical Spike Soderburg	Dry electrostatic precipitator followed by crossflow packed-bed wet scrubber*	99
Horizontal Spike Soderburg	Wet electrostatic precipitator followed by crossflow packed-bed wet scrubber*	99

*Scrubbing water must be treated for water pollution control.

At the control levels indicated, it is estimated that particulate emissions from the primary aluminum industry would be 5,090 tons in FY 1977.

Required investment and annualized control costs have been estimated, by company, on the basis of projected FY 1977 capacity and summed for the industry as a whole. The required investment through FY 1977 is estimated to total $922.8 million, and the annual cost of control for that year is estimated to total $256.4 million.

Net annual control cost per ton of capacity, after allowance for recovery of valuable materials from the control devices, is lowest for firms using the prebaked process--vertical spike Soderberg cells cost 1.6 times as much per ton, and horizontal spike cells cost 2.8 as much. Depending on the proportions of systems used, firms with some Soderberg cells will experience an average annual control cost ranging from 10 to 100 percent higher per ton of capacity than those required of firms using prebaked cells only.

For the industry as a whole, annual control cost per ton of production in FY 1977 is estimated to average $44.14. For firms using only the prebaked process, it is estimated to be $14 less per ton.

4. Scope and Limitations of Analysis

The engineering and control cost data summarized above give a firm basis for estimating the costs of control of particulate emissions for individual firms and the total industry. Besides particulates, there are other significant pollutant emissions from aluminum plants (e.g., flourides), but because they are not at this time subject to specific emission standards, they have not been included. Adequate financial data on which to base the estimation of the impact of these costs on firms and the markets are also available; however, because relatively few firms are involved, hypothetical model firms were not used to illustrate cost impact. To avoid specifying costs for actual individual firms (a procedure which may involve factors such as the overall financing program of the firm and the intricacies of its tax position not considered in this study), the impact is discussed in relation to general trends and patterns which are expected within the industry and the markets.

5. Industry Structure

In 1967 there were eight primary producers of aluminum, operating 24 plants. Between 1967 and 1971, five firms entered the industry and a sixth is scheduled within the next year. Each of these new firms will operate only one plant during the period covered by this study, according to their announced plans.

Plant capacity ranges from 35,000 to 335,000 tons per year. Plants using the prebaked process cover the whole size range; horizontal spike Soderberg plants range from 195,000 to 220,000 tons per year, and vertical spike Soderberg plants range from 100,000 to 195,000 tons per year.

The industry continues to be dominated by the three largest primary producers, but their share of productive capacity has fallen from more than three-fourths in 1967 to less than two-thirds in 1971 and may approach one-half by 1977. Among the new firms entering the market since 1967 are several that are primarily engaged in the production of other nonferrous metals, strongly indicating continuation of the trend toward an integrated nonferrous metals industry. More steel firms are also entering the industry. Several other new firms are wholly or partly owned by major foreign producers of aluminum.

New construction and expansion of existing facilities caused a rapid expansion of capacity in 1969 and 1970. A strong but somewhat slower expansionary trend is indicated through 1977. The average growth rate from 1967 to 1977 in capacity has increased to 5.25 percent annually from the previous 4.4 percent. The growth rate for production remains unchanged at 5.8 percent annually.

6. Market

Market growth for aluminum has resulted from the development of new aluminum-using products and from intensive competition to replace other metals with aluminum in traditional uses. However, aluminum faces strong competition from various plastics in some uses. A major factor in the sales growth of aluminum has been its ability to deliver a fully satisfactory substitute for copper or steel at a significant cost reduction.

Important markets for aluminum include automobiles, construction, electrical products, consumer durables, and containers. In each of these industries, aluminum has significant advantages in cost and technical factors for certain uses, but seldom has sufficient advantage to forestall competition from other materials. Therefore, despite its concentration, the industry faces a highly competitive market with substantial price sensitivity.

The major areas of strong competition between aluminum and plastics are motor vehicles and equipment and miscellaneous transportation equipment (primarily small boats). Aluminum and plastics usage in motor vehicles is growing at the expense of various other metals, textiles, hardboard, glass, and nonmetal materials. Applications of aluminum include trim, motor blocks, housings for differentials, transmissions and generators, power steering and brake assemblies, and radiators. Plastics are used, or are expected to be used, for gas tanks, steering wheel housings, engine oil pans, battery trays, fan blades, lights and lenses, cowel panels, glove compartment doors, fender extensions, exterior trim, wheel covers, and air intake filters. The greatest competition between aluminum and plastics is for interior and exterior trim items.

The miscellaneous transportation industries include shipbuilding and boatbuilding and repairing and the railroad equipment industries. More aluminum is expected to be used because of its high strength to weight ratio. Currently plastics and aluminum account for over 90 percent of all materials used in small boats. A continuation of the upward price trend for aluminum and the downward trend for plastics will cut into this market for aluminum.

Exports account for approximately 8 percent of shipments of aluminum. This market is not expected to grow in the next 5 years because capacity in other countries is expected to increase about 60 percent. Imports have risen sharply this year, and a trade deficit of about 900 million pounds is projected. This compares to a surplus of 296 million pounds in 1970.

It is anticipated that the use of aluminum will again increase as the total economy picks up strength. In addition, it is anticipated that the price of primary aluminum would continue to rise over the next 6 years, even in the absence of control costs, following the trend set in the 1960's. Because this pattern of price increases has been more moderate than that for copper and steel, aluminum has enjoyed a competitive price advantage that has been reflected in the substitution of aluminum for other materials, particularly in the electrical and automobile industries. Continuation of this pattern justifies the projection of a higher rate of growth of production of aluminum than for copper, particularly, through FY 1977.

Within the industry, prices tend to be very similar from firm to firm, since four firms in the United States and Canada control approximately 65 percent of the world's output.

7. Economic Impact of Control Costs

Many of the firms in the aluminum industry have recently been operating as much as 20 percentage points below their best operating ratio of close to 100 percent, indicating excess capacity for the present market. For these firms, profit levels are well below normal. It is probable that these conditions will persist for several years, until demand more nearly matches capacity, which will depend in part on how rapidly the general economy improves.

For this analysis it has been assumed that the industry will be back on its longrun growth curve before FY 1977. Implementation of controls will probably take place between Fiscal Years 1973 and 1975, so until then, profits of some firms may be temporarily depressed. In the longer run, however, it is expected that most firms will shift the major share of annual control cost into price. The history of the industry clearly indicates that cost increases are translated into price increases, usually within 3 years, reflecting the substantial market power of these firms.

One factor acting against too rapid a price increase for aluminum is its competitive position with other metals and with plastics. Steel and copper in particular are competitors in several markets for aluminum, and the price advantage which aluminum has enjoyed in electrical products and certain structurals has contributed to the growth of aluminum sales more than proportionately to the 25 to 30 percent of the aluminum market that they represent. The percentage increase in the price of aluminum depends on the percentage rise in the price of copper. In steel-competitive markets, aluminum prices will probably not rise as much as in copper-competitive markets. These are reasons why the increase in aluminum price is expected to be less than the average control cost per pound of metal.

Other factors may limit price increases in the aluminum market. The differential cost of production processes is such that a company operating prebaked cells would need a price increase of only $0.018 per pound to maintain its revenue from sales. Since plants of this type dominate the industry, it is unlikely that the price of aluminum can increase by $0.024, the average control cost for the industry. Without an increase of at least this magnitude, however, it appears that at least two major firms will find earnings from one-third to one-half of their production significantly cut and their overall profits thereby reduced. These firms have significant production capacity in horizontal spike cells which are expensive to control relative to other cell types.

The worldwide nature of the aluminum market is also a factor militating against price increases in excess of those induced by market demand. Foreign producers may increase marketing in the United States to an extent sufficient to limit price increases.

The most likely conclusion of this analysis is, therefore, that by FY 1977 the price of aluminum will rise by not more than $0.02 per pound over the price that otherwise would prevail. This price increase may have a significant adverse effect on the competitive position of aluminum versus competing materials and at the same time will not permit all firms to recover their control cost. All the firms involved appear to be strong enough, however, to absorb a part of the required cost and adjust to market changes without the necessity of basic changes in structures or operations. All firms also appear able to absorb the required control investment outlays into their investment programs without substantial financial difficulties.

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N. Primary Copper, Lead, and Zinc

1. Introduction

a. Nature of Product and Process

Primary copper, lead, and zinc metals are produced from beneficiated mineral ores through process steps involving roasting, high temperature smelting, oxidation, and finally, refining. The mineral ores contain the metals in very small quantities--natural mineral cupric sulfide ores in the U.S. contain about 1.0 percent metallic copper--and are beneficiated to produce metal concentrates for the economic extraction of the respective minerals. Copper ores also contain iron, sulfur, silica, and minute quantities of arsenic, cadmium, antimony, bismuth, gold, and silver. Lead and zinc ores contain a higher percentage of the metal and fewer impurities.

For this study the process considered is extraction or smelting. In copper extraction, the smelter consists of a reverberatory furnace and converters (some smelters also have roasters). The reverberatory furnace melts the metal charge to form copper matte containing silica and iron along with the copper. In the converters, air charges blown into the liquid matte separate the remaining iron and produce resulting blister copper, 99 percent pure, which is either cast or shipped to other plants for final refining.

Zinc sulfide concentrates are roasted in Ropp, multiple-hearth, or other types of roasters to separate the sulfur from zinc. In the roasting step, the zinc sulfide is converted to zinc oxide calcine. Sintering machines are then used to agglomerate the calcine material. Recycled dusts and other valuable materials are added to the sintering to produce the final zinc-bearing agglomerates. Metallic zinc is extracted by electrolytic deposition or by distillation in retorts or furnaces. Electrolytic deposition requires a preliminary step of leaching zinc calcine with sulfuric acid to form zinc sulfate for the electrolysis step.

Primary lead smelting is similar to zinc smelting in that the first treatment is sintering for separation of sulfur from the desired metal. The sintered product is lead oxide, which is reduced to lead in a blast furnace and further purified in a lead refining furnace.

b. Emissions and Cost of Control

Sulfur dioxide is the primary pollutant emitted from the smelting of copper, lead, and zinc ore concentrates. Sources of emission are roasters, reverberatory furnaces, converters, and sinter machines. The emissions are characterized by heavy mass rates and relatively weak flue gas concentrations from reverberatory furnaces and uneven pulsating flows from converters. In addition, the flows are contaminated with small quantities of materials harmful to human health, such as arsenic, bismuth, cadmium, and mercury. These factors also make the collection of sulfur pollutants difficult and costly.

COPPER SMELTERS - Generally, sulfur dioxide emissions from reverberatory furnaces and converters are uncontrolled. Control techniques depend on the size of the furnaces, gas flows, emission rates, plant condition, and degree of obsolescence of present smelters. (Average age of existing smelters is 40 years.) For some plants, reverberatory furnaces may have to be replaced with flash smelters; flue ventilation systems will have to undergo extensive modification, and converters may have to receive oxygen enrichment to produce gas volumes sufficiently small for less expensive control facilities. Control techniques costed for this report take into account the costs of calcium sulfate and sulfuric acid recovery and modifications of dry precipitators and flue gas flows. Other production and process improvements are not included.

The investment required for copper smelters is $313 million. Annual costs are $100 million by FY 1977 with full implementation of controls. Assumed for all three primary nonferrous industries was depreciation of 15 years, interest rate of 8 percent, and taxes and insurance of 2 percent. No credits were assumed for collected byproducts for any of the three industries.

The 1967 emission level of 2.58 million tons of sulfur dioxides will increase to 3.34 million tons in 1977 without new controls; full implementation will reduce the level to 535,000 tons. The 1967 emission level of particulates of 243,000 tons will increase to 314,000 tons in FY 1977 without net controls; full implementation of the abatement strategy for sulfur dioxides will reduce particulates to 286,000 tons.

LEAD SMELTERS - The emission of sulfur oxides is primarily from sinter machines which account for about 98 percent of total lead smelter emissions. The gas volume flow is steady from the sinter machine and is of sufficient sulfur dioxide strength (about 5 percent) for acid recovery. Unlike the copper industry, lead smelters have already installed sufficiently efficient particulate collectors, and replacements are not required. The cost estimates are therefore lower by the amount.

The investment for sulfur acid recovery plants to control emissions in the lead industry is estimated to be $65 million, and annual costs are estimated at $15.6 million for full implementation by FY 1977.

In 1967, lead smelters emitted 185,000 tons of sulfur oxides. As a result of abatement, the industry's emissions should decrease from a projected 213,000 tons to 29,000 tons annually by FY 1977. The 1967 level of particulates was 34,000 tons. Particulates should be reduced from a potential 39,000 tons in FY 1977 to 26,000 tons as a result of implementing the abatement strategy for sulfur dioxide.

ZINC SMELTERS - The emissions of sulfur oxide from zinc smelters are basically from those plants that emit dilute off-gas from roasters and sinter machines. These gas streams usually contain about 0.5 to 1.0 percent in sulfur dioxide strength. Recovering sulfuric acid from such a diluted gas is costly. (Zinc plants that do recover sulfuric acid have concentrated sulfur dioxide gas streams.) Like the lead industry, dry collectors are not included in the cost estimates, and it is assumed that the limestone scrubbers used for removing sulfur dioxide emissions will also sufficiently remove particulates. Investment required for the zinc industry amounts to $40.7 million, and annual costs under full implementation are estimated to be $17.7 million by FY 1977.

The assumed controls should reduce the estimated FY 1977 emission level of 555,000 tons of sulfur dioxide to 138,000 tons. (Emissions for 1967 were 446,000 tons.) Particulates emitted in 1967 were 57,000 tons; the FY 1977 level of 71,000 tons will not be affected significantly by the abatement strategy for sulfur dioxide.

c. Scope and Limitations of Analysis

Data for this report were obtained primarily from trade, industry, financial, and government documents, journals, and newspapers. Financial analysis of firm impact was hampered by the diverse nature of firms within the industry, and by the failure of integrated firms to disclose profit by product. Because of the variance of integration--degree as well as kind--within the industry, construction and incorporation of a model firm to gauge financial impact was not included in this report. In its place are conclusions drawn from a firm-by-firm financial analysis which included examination of capital structure and cash flows.

2. Engineering Basis of Analysis

a. Emissions

The basis for determining present emissions (1967) and control levels was the Arthur G. McKee Study for sulfur dioxide and the Midwest Research Institute Study for particulates. Typical sulfur dioxide emission rates for the various smelters are shown in Tables 4-67 and 4-69. The breakdown of sulfur oxides is available for 1969 and has been adapted as shown in Table 4-69 to project backward to 1967 to determine emissions for that year.

Emission rates for various sources of particulates are shown in Table 4-68, as well as the emission levels and associated percent of control. In the analysis, only those sources contributing to sulfur oxides were considered for reduction of particulates. The control strategies for sulfur oxides will have the added benefit of achieving particulate control levels on the order of 96 to 98 percent for copper

TABLE 4-67. EMISSIONS OF SULFUR DIOXIDE FOR U.S. NONFERROUS SMELTERS, 1969

TYPE SMELTER	SO_2 GENERATED, 1000 TONS PER YEAR	SO_2 EMISSIONS, 1000 TONS PER YEAR
Copper		
Roasters	720	466
Reverb Furnaces	782	782
Converters	2129	1694
Zinc		
Roasters	1394	472
Sinter-Roast Machines	120	120
Sintering Machines	45	45
Cokers and Retorts	5	5
Lead		
Sintering Machines	341	246
Blast Furnaces	6	6
Other	11	11
TOTAL	5553	3847

Reference: Semrau, Konrad T., "Sulfur Oxides Control and Metallurgical Technology", Presentation to EMD-AIME Copper Metallurgy Institute, Denver, February 17, 1970.

TABLE 4-68. EMISSIONS OF PARTICULATES FOR U.S. SMELTERS, 1967

TYPE SMELTER	EMISSION FACTOR,	EMISSIONS, 1000 TONS PER YEAR	CONTROL LEVEL, PERCENT
Copper			
Roaster	168 lb/ton copper	7	85
Reverb Furnaces	206 lb/ton copper	28	81
Converters	235 lb/ton copper	33	81
Ore Crushing	2 lb/ton ore	170	0
Handling	10 lb/ton ore	5	32
Zinc			
Roasters (Fluid)	2000 lb/ton zinc	15	96
Roasters (Ropp)	335 lb/ton zinc	4	85
Sintering	180 lb/ton zinc	3	95
Ore Crushing	2 lb/ton ore	18	0
Distillation	50 lb/ton zinc	15	0
Handling	7 lb/ton zinc	2	32
Lead			
Sintering	520 lb/ton lead	17	86
Blast Furnaces	250 lb/ton lead	10	83
Ore Crushing	2 lb/ton ore	4	0
Dross Reverberatory	20 lb/ton lead	2	50
Material Handling	5 lb/ton lead	1	32

Source: Midwest Research Institute

TABLE 4-69. MODEL PLANT DESCRIPTIONS FOR COPPER SMELTERS

Processes	MODEL A Roaster, Reverberatory, Converters (2)	MODEL B Reverberatory and Converters (2)	MODEL C Reverberatory and Converters (4)
Production, Tons Copper/Year	75,900	75,900	150,000
Present Control	45%	0	0
Required Control Scheme	Limestone Scrubbing	Acid Plant	Acid Plant
Tons Sulfur in Ore Feed per Day	367	256	512
Tons Sulfur Captured in Slag or Other	201	12	24
Sulfur Emissions, Tons Per Day	166	244	488
Allowable Plant Emissions, TPD	36.7	25.6	51.2
Required Additional Removal, %	77.9	89.5	89.5
Reverberatory Gas Volume,			
(a) Before Control (SCFM)	52,000	90,000	180,000
(b) After Control	30,000	48,500	97,000
Converters, Peak Volume, SCFM			
(a) Before Control	67,000	70,000	140,000
(b) After Control	40,000	40,000	80,000

roasters, converters, and reverberatory furnaces, and zinc Ropp roasters, and lead sinter machines.

b. Copper

The control costs for the primary copper smelting industry were based on three model plant configurations shown in Table 4-70. The relationships for gas volumes, production rates, and sulfur emissions are taken from the Arthur G. McKee study. The reduced gas volumes shown are consistent with the methodology for concentration of sulfur in flue gases as outlined in the Fluor-Utah study. Cost data developed for each model plant configuration were based on unit costs presented in the Fluor-Utah study report. These data are shown in Table 4-70. Although the unit costs for various elements such as acid plants, precipitators, and scrubbers are the same as those presented in the Fluor-Utah study, the selection of control strategies for each model and hence, the total costs, will differ from data presented in the latter study.

The rationale for selecting control strategies assumes scrubbing of dilute gas streams with limestone slurries and processing concentrated sulfur-laden gases into sulfuric acid. Based on this rationale, Model A uses limestone scrubbing for both reverberatory and converter gases. Model A is applied to smelters smaller than 76,000 tons per year and to smelters that practice some degree of control. Model B combines one-half of the reverberatory furnace gas with the converter gases for processing in a single acid plant. The remaining half of the reverberatory off-gas goes to a limestone scrubber unit. For Model C, all gases are treated in an acid plant. Wherever limestone scrubbing is used, two scrubbers in parallel are assumed for costing purposes. This is to assure operation in case of breakdown in the one unit under operation.

Investment and operating costs were developed individually for 15 smelters based on data reported by the McKee study. To determine control requirement costs, a combination of 5 plants for Model A, 7 plants for Model B, and 3 plants for Model C was used to develop the aggregate costs.

New sources were costed out on the basis of the Model C

TABLE 4-70. COST COMPOSITIONS FOR COPPER MODEL PLANTS

	MODEL A	MODEL B	MODEL C
Investments ($ millions)			
(a) Dry Precipitators		4.99	7.36
(b) Flues Modification	1.07	1.12	1.70
(c) Waste Heat Boiler	0.17	0.18	0.26
(d) Limestone Grinder	3.17	1.40	
(e) Gypsum Disposal	0.33	0.20	
(f) Scrubbers (2)	1.50	1.26	
(g) Wet Gas Cleaning		3.35	5.37
(h) Acid Plant		3.08	4.77
(i) Acid Storage		0.73	1.27
(j) Site Preparation	0.70	1.63	2.07
(k) Off-Site Facilities	0.70	1.63	2.07
TOTAL	7.64	19.57	24.87
Annual Costs ($ millions)			
(a) Labor	0.08	0.20	0.16
(b) Power	0.50	0.43	0.46
(c) Chemicals	2.36	0.51	
(d) Water	0.26	0.05	
(e) Steam		0.07	
(f) Maintenance	0.22	0.59	0.30
(g) Depreciation	0.50	1.30	1.66
(h) Interest, Taxes, Insurance	0.75	1.96	2.49
TOTAL	4.67	5.11	5.07

smelter, after removing costs for dry precipitators, flue modifications, and their related offsite facility and site clearance costs. It is not known at the present time what type of furnaces will be included in any expansion program. However, it is assumed that any new type of furnace will require an acid plant and its ancillary facilities. For new sources, a total annual capacity of 490,000 tons of copper was projected for the necessary expansion.

c. Lead

Lead smelters basically have a problem of sulfur oxides from their sintering machines. Most of the machines in operation are of the downdraft type. Their design allows for a large amount of air leakage, which results in a sulfur dioxide concentration too low for economic production of sulfuric acid. A model plant was developed which would incorporate some recycling of gases to enrich the sulfur dioxide to 5.0 percent. The basis for unit costs was taken from the Fluor-Utah study. The model plant description and costs are shown in Table 4-71. Costs were scaled to individual plants in accordance with production and capacity characteristics of each. Five smelters were assumed to install control facilities. No additional controls for particulates, other than the wet gas cleaning units shown in Table 4-71, were assumed to be required.

d. Zinc

Zinc smelters have roasting and sintering operations, both of which are conductive to sulfur emissions and particulates. Roasters which remove sulfur from the zinc sulfide concentrates may be Ropp suspension, multiple-hearth, and fluidized types. The Ropp roasters which are employed in the older smelters give rise to dilute gas streams, in terms of SO_2 concentrations. For these types of roasters, only limestone scrubbing could be considered a viable solution to meeting the emission limitation. The model plant shown in Table 4-72 shows the engineering data and costs for meeting the assumed emission limitation imposed for sulfur dioxide. Again, the data source for costs is the Fluor-Utah study. Six zinc smelters were assumed to undergo investments for limestone scrubbers.

TABLE 4-71. LEAD SMELTER MODEL

Production	47,000 TPY
SO_2 Emission	68,000 TPY
Gas Volume to Acid Plant	85,000 SCFM
SO_2 Concentration	5%
Investment ($ millions)	
Flue Gas Modification	1.76
Wet Gas Cleaning	2.65
Acid Plant	2.93
Acid Storage	0.39
Site Preparation	0.77
Offsite Facilities	0.77
TOTAL	9.28
Annual Costs ($ millions)	
Labor	0.079
Power	0.227
Water	NIL
Maintenance	0.240
Depreciation	0.518
Interests, Taxes	0.928
TOTAL	2.092

TABLE 4-72. ZINC SMELTER MODEL

Production	92,000 TPY
SO_2 Emission	90,000 TPY
Gas Volume to Scrubbers	100,000 SCFM
SO_2 Concentration	2%
Investment ($ millions)	
Flue Gas Modification	1.94
Limestone Grinder	2.81
Gypsum Storage, Disposal	0.28
Scrubber	1.17
Site Preparation	0.62
Offsite Facilities	0.62
TOTAL	7.44
Annual ($ millions)	
Labor	0.079
Power	0.690
Limestone	1.490
Water	0.391
Maintenance	0.174
Depreciation	0.495
Interest, Taxes	0.744
TOTAL	4.063

3. Industry Structure

a. Characteristics of the Firms

In 1967 there were 19 copper smelters, 6 lead smelters, and 15 zinc smelters in the United States. At present (1971) there are 16 copper smelters representing the U.S. smelting capacity of 8 firms; 7 lead smelters representing the U.S. smelting capacity of 6 firms; and 8 zinc smelters representing the U.S. smelting capacity of 7 firms. Estimation of smelting capacity is hindered by variations within the industry of the quantity and quality of ores, roasting and sintering capacity, and blast furnace capacity at individual smelters.

The annual mill capacity in terms of materials handled for U.S. copper smelters for 1970 was 8,689,000 short tons. Copper smelter annual capacities for 1967 ranged from 16,000 to 330,000 tons and averaged 101,000 tons. U.S. capacity in 1970 in terms of materials handled for smelters of non-Missouri lead was 1,530,000 tons. Plant capacities range from 300,000 to 420,000 tons with an average of 382,500 tons. Smelting and refining operations of Missouri lead had an annual capacity of 415,000 tons of pig lead. Smelter capacities ranged from 90,000 to 225,000 tons with an average of 138,333 tons. Capacity of zinc smelters for 1970 in the United States was 904,000 tons of slab zinc. Capacities for smelters ranged from 16,000 to 250,000 tons with an average of 90,000 tons.

Unlike zinc smelters, copper and lead smelters are located near the mine sites. Most copper smelters are in the western part of the United States, with the largest amount of copper, in terms of tonnage of materials handled, being smelted in Arizona. Most lead smelters are also found in the Western United States, with the largest smelter capacity located in Missouri.

Copper smelting firms are, for the most part, vertically as well as horizontally integrated. Among the 8 firms, 7 are principal sellers and refiners of copper, and 3 are also smelters of lead and zinc. Some also have operations in foreign countries.

b. Resources

COPPER - The major raw material (ore) of copper smelters has been declining in grade. The average recoverable content of U.S. ores declined to an alltime low of 0.60 percent in 1968. This is explained in part by the increasing demand for copper which made production from lower grade ores economical and, in turn, by an increase in the quantity of materials handled at the mine and smelter and thus the costs that go with deeper mines and benefication required to produce copper from these ores. As production has increased, the work force has remained constant for about the last 2 decades.

LEAD - Lead ores are obtained primarily from underground mines. The cost is a function of grade, location, and coproducts. Although higher in grade, the ores in the far Western States are more expensive to mine than those in Missouri. Increased use of mechanized equipment has increased the skill level required in the industry. The more capital intensive techniques and the more highly skilled work force have, in turn, resulted in an upward trend in productivity.

ZINC - Zinc ores too are obtained primarily from underground mines. Mining costs vary widely depending on ore quality, quantity, and location. Labor accounts for about 50 percent of the direct mining costs. Productivity has increased, but the labor force employed has decreased due to newer technologies which require a smaller but more highly skilled labor force.

3. Market

The form of copper, lead, and zinc coming out of the smelters requires further refining and processing, which is done in many cases by the same firm that smelts the ore.

a. Competitive Products

COPPER - Aluminum, plastics, steel, and glass serve as close substitutes for copper. Superconductive alloys for cables in the communications area will add to the increased competition copper receives from aluminum. Aluminum and stainless steel also compete with copper in the building industry. Plastics, a substitute for copper primarily in the tubing area, may find an even more favorable competitive position if building codes are relaxed to allow use of plastics as well as copper.

The industry has sought recently to combat this competition with increased efforts in market development activities. Projects undertaken include the copper electric car, the sovent plumbing system, the desalting test loop, and a copper data information center. In addition, more economical ways are being sought to metallurgically bond copper with other materials.

LEAD - Lead substitutes include cadmium, nickel, silver, zinc, titanium, polyethylene, plastics, galvanized steel, copper, cement, and aluminum. Cadmium, nickel, silver, and zinc are substitutes for lead in the production of specialized storage batteries. Titanium and zinc pigments are steadily replacing lead in interior as well as exterior house paints, but not in paints used to provide for rust and corrosion protection. Polyethylene, along with metallic and organic materials has served as replacement for lead in underground cable coverings. Plastics, galvanized steel, copper, aluminum, and cement compete with lead in construction needs.

The industry has attempted to create new products and to improve existing ones. In the vehicle propulsion field, the battery-powered vehicle used for short driving distances seems to present a future market for lead acid batteries. In most of the other market development areas, industry has sought to combine the advantages of lead with those of other materials to create a highly competitive product. Examples include lead-plastic sheathing materials, lead-plastic container materials, lead-plated steel (processed at high speeds), and lead-bearing enamel for aluminum.

ZINC - Aluminum, magnesium, plastics, cadmium, and specialty steels are substitutes for zinc. Aluminum and magnesium, along with plastics, compete with zinc in die casting. For low tonnage anticorrosion requirements, ceramic and plastic coatings, specialty steels, and electroplated cadmium and aluminum are substitutes. Aluminum competes with zinc in roofing and siding. In the paint and ceramic industries, titanium pigments are a close substitute.

Zinc has been replaced to some extent as a reducing agent in chemical reactions by aluminum and magnesium.

Research efforts have been underway to develop applications of zinc coatings in areas not only where its corrosion protection characteristics are required, but also where cyclic loading and welding are important. Other areas of research include zinc-fin radiators, zinc wheels, and wrought zinc tubing.

b. Distribution

The major end uses of copper are in electrical equipment and supplies, used in construction, industrial machinery, transportation, and ordnance. Lead is used primarily in transportation, construction, ordnance, packaging, communications equipment, and printing and publishing. End users of zinc include construction, transportation, pigments and compounds, plumbing and heating, and industrial machinery.

Other supplies of these metals include secondary smelting and importing. Imports are in the form of ore and/or refined metals. About 16 percent of the copper produced in the United States is from secondary smelting. Of the total U.S. refined copper production, about 12 percent is from foreign ores. The United States is a net importer of unrefined copper and a net exporter of refined copper.

About half of the lead produced in the United States is from secondary smelting. Approximately 20 percent of the lead refined in the United States is from imported ores. The United States is a net importer of lead.

Secondary smelting accounts for 20 percent of the U.S. zinc production. About 50 percent of the U.S. refined slab zinc production is from imported ores, and the United States is also a net importer of refined zinc.

c. Protection: Taxes, Tariffs, Government Stockpiling

COPPER - U.S. copper producers receive a 15 percent depletion allowance for their domestic as well as foreign operations. Duties on copper ore and metal imports suspended to July 30, 1970, by Public Law 90-165 will be lowered yearly to January 1, 1972, when 0.8 cents per pound will be charged on ore and unwrought copper, waste, and scrap. The government stockpile was about 260,000 tons at the end of 1968 with no order at present for enlarging the stockpile.

LEAD - The lead industry receives a 23 percent depletion allowance on domestic production and 15 percent on foreign production. Present import duties on ore are 0.75 cents per pound of lead in ore and 1.0625 cents per pound of lead metal. A price support of 75 percent of the difference between 14.5 cents per pound of contained lead and the average monthly market price for common lead at New York is maintained. Lead is also a stockpiled mineral with a present surplus position.

ZINC - The zinc industry also receives a 23 percent depletion allowance on domestic production and a 15 percent allowance on foreign production. The free world duty on zinc ore and fume is 0.67 cents per pound and for zinc metal is 0.7 cents per pound. (The respective duty for some communist countries is 1.67 cents per pound and 1.75 cents per pound.) The government stockpile of zinc is nearly double the target set in 1969. The price support level is 75 percent of the difference between 14.5 cents per pound of contained zinc and the average monthly market price for prime western zinc at East St. Louis.

4. Industry Trends

Investment funds have been expended for mine exploration and development at the expense of smelter modernization. The tax advantages of the depletion allowance encourage mining large quantities of ore and building ore reserves.

a. Copper

Near record output from domestic mines and smelters plus a general slowdown of the world economy have led to an easing of copper prices. However, current nationalization actions and industry strikes may be expected to cause prices to rise somewhat in the future.

b. Lead

Uninterrupted production from new mines and smelters in the late 1960's put U.S. ore and refined lead output at record levels in 1969. However, the slowdown of the national economy together with increased lead supplies has resulted in a softening of lead prices. Moreover, the possible regulations against the usage of tetraethyl and tetramethyl lead in gasoline will adversely affect prices over the next 5 years.

c. Zinc

Production and consumption of zinc was up in 1968, although zinc prices have not declined as have those of copper and lead, but the demand has been weakened recently due primarily to the slowdown in the national economy, the auto strike, and the trend toward smaller cars. The price rise has not been enough to offset the declining demand. The result has been the closing of some marginal smelting operations and, in some cases, moving these operations to mine sites abroad.

5. Economic Impact of Control Costs

a. Impact on Firms Within the Industry

Examination of balance sheets and income statements for most of the firms engaged in primary copper, lead, and zinc smelting has led to the overall conclusion that sufficient cash flows could be generated to pay the annualized control costs. Effects of control costs on profits and return on investment (ROI) vary throughout the industry, but they would not be severe enough to warrant plant closing. With the additional burden of air pollution control costs, smelters located away from mine sites may try to reduce total operating costs by moving the plant to the mine site.

b. Impact on the Industry

Industry impact is a function not only of economic and market development trends but also the air pollution control expenditures incurred by the producers of close substitutes and the cost-shifting practices of these competitors (some primary nonferrous firms also produce substitute products).

Projected annual U.S. growth in demand through FY 1977 for copper, lead, and zinc is 2.6 percent, 1.4 percent, and 2.2 percent, respectively. The primary producers' share of the market will depend on the product mix and the extent of the air pollution control cost shifting by secondary producers. The market share of primary copper producers should remain the same. The likelihood, however, of requirements for unleaded gasoline and the loss of a large portion of the current market for primary lead indicate that most of the growth forecast for lead consumption will be satisfied by secondary producers. The shares of primary and secondary zinc producers in satisfying projected demand should remain the same; however, it is likely that more primary needs will be satisfied by smelters located near mine sites in foreign countries.

c. Demand Elasticity and Cost Shifting

Most of the factors affecting demand elasticity and cost shifting have been discussed earlier in this report, but no mention has been made of the control costs for producers of close substitutes and whether these costs would be shifted. Producers of secondary copper, lead, and zinc will probably pass on fully their control costs. Producers of close substitutes such as primary aluminum and steel will also be faced with rather significant cost increases. Control costs to be experienced by most primary smelters of copper, lead, and zinc are 3.2 cents per pound, 2.2 cents per pound, and 2.2 cents per pound, respectively.

Producers will probably be able to pass on only a portion of these added costs. This will depend primarily upon future world market conditions, and as such is highly unpredictable. The future market for copper will be dependent primarily upon the action of the foreign governments which have recently nationalized production. The lead industry currently faces a longrun decline in demand because of the expended trends toward low-lead gasoline and smaller cars. The future demand for zinc appears to be growing steadily. This suggests that zinc producers will have the least difficulty in passing on cost increases; and lead producers the most difficulty. No statement can be made about the magnitude of such increases.

REFERENCES FOR SUBSECTION N

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O. Secondary Nonferrous Metals

1. Introduction

Four industries encompassing those firms that reprocess copper, aluminum, lead, and zinc scrap will be covered in this section. Although mutually integrated to some extent, each will be individually considered where practical.

a. Nature of Product and Process

COPPER - The secondary copper industry produces about 35 percent of the total copper consumed in the United States. Most output in the form of unalloyed metal is reclaimed by the primary copper producers as electrolytic copper and is not considered in this section of the report. Of the remaining secondary production, virtually all of the metal is recovered in alloy form.

Almost all the copper-based alloys are brass or bronze, although several are actually misnamed. Technically, brass is a copper-based alloy with zinc as the major secondary component. Bronze is copper-based with tin as the major secondary component. Lead, iron, aluminum, nickel, silicon, and manganese appear in certain classifications. The choice of the specific alloy composition is dependent upon the stress, corrosion, and machining conditions to which the product will be subjected.

The basic raw material of the brass and bronze industry is copper-bearing scrap from obsolete consumer and industrial products. The scrap is often contaminated with metallic and nonmetallic impurities and thus usually requires some preprocessing. Common techniques include hand sorting, magnetizing to remove tramp iron, stripping or burning to remove insulation, sweating to remove low-melting-point metals, and gravity separation in a water medium to concentrate fine copper-bearing materials.

Cleaned scrap is charged into a furnace where it is melted, smelted, refined, and alloyed to meet the specifications for one of several standard brass and bronze products. The most common type of furnace in use in the industry is the stationary reverberatory furnace which can vary from 10 to 100 tons in batch capacity and from 24 to 48 hours in batch processing time. Cylindrical rotary furnaces are used for smaller batches, seldom exceeding 30 tons, and crucible furnaces are used for even smaller quantities or for special purpose alloys.

ALUMINUM - The secondary aluminum industry produced 18.7 percent of the nation's aluminum supply in 1967. It processes scrap into finished alloys of varying consistencies. Approximately 90 percent of output is consumed by the casting sector of the aluminum fabricating industry, represented by nearly 2,800 small, independent and captive foundries.

There are four major steps in processing: (1) sorting and preparing the scrap; (2) smelting the feed in reverberatory furnaces or, occasionally, in small rotary furnaces; (3) cleansing and refining the molten metal by fluxing and filtration; and (4) pouring the finished alloy into molds for cooling and hardening.

LEAD - The secondary lead industry accounted for 59 percent of domestic production and 44 percent of the nation's lead consumption in 1967. It processes lead scrap into lead oxide and various alloys and fabricates the recovered metal into many final products, including storage batteries, paint pigments, solder and type, cable coverings, and castings.

There are four major steps in the recovery of lead: (1) sorting and preparing the scrap; (2) smelting the feed in reverberatory furnaces or, occasionally, in cupolas; (3) refining and purifying the molten metal by oxidation of impurities and, if lead oxide drosses are charged to the furnace, reduction to metallic lead with the addition of carbon; and (4) intermittently tapping the finished metal for molding.

ZINC - In 1967, zinc recovered from scrapped materials accounted for 17 percent of the national output of that metal. Slightly over half of this recovery was performed by primary zinc producers and chemical plants, and the remainder by firms principally engaged in secondary smelting. Only the latter are considered in this section.

Most of the zinc recovered by the secondary industry is in the form of redistilled slab or zinc dust. The metal is sold in the same markets as primary zinc--construction, transportation, electrical equipment and supplies, plumbing and heating, industrial machinery, and pigments and compounds. The principal steps in processing zinc scrap are as follows: (1) sorting and preparing the scrap; (2) melting or sweating; and (3) refining the zinc metal through distillation.

b. Emissions and Cost of Control

COPPER - The refining furnace is the principal source of particulate emissions in the brass and bronze industry. Refining is a process in which a flux is used to remove metallic impurities from the metal. By far the most commonly used flux is compressed air (oxygen), which is bubbled through the molten metal to oxidize impurities. The oxides so formed are lighter than the molten metal and are removed from the melt by entrapment in the slag covering or by entrainment in the gases leaving the furnace. The most volatile metal oxides (especially zinc and lead) condense to form very fine (submicron) fumes which are extremely difficult to collect. In addition to the metallic oxides, fly ash, carbon, and mechanically produced dust are often present in the furnace exhaust gases. The exact composition of the particulate matter depends upon the fuel used, alloy composition, melting temperature, furnace type, and many operating characteristics.

Particulate emissions from the brass and bronze industry were estimated to be 11,000 tons in 1967. Maintenance of the 1967 control level of 57 percent would increase emissions to 14,000 tons by FY 1977. The installation of fabric filters would achieve the process weight code requirements by reducing emissions to 1,600 tons in FY 1977; the implementation of these control systems would require approximately $2.6 million in investment costs and $.5 million in annual costs.

ALUMINUM - The most severe air pollution problem in the processing of secondary aluminum occurs when chlorine is used as a fluxing agent. As chlorine is bubbled through the molten metal, it both agitates the bath and combines with certain impurities such as magnesium and dissolved hydrogen. The fumes vented from the furnace include $AlCl_3$, Al_2O_3, and HCl and unreacted chlorine. This presents an extremely difficult control situation because of the corrosiveness of the acid mist and the fact that much of the particulate matter is in the submicron size range.

Aluminum sweating furnaces present a smaller but still significant problem: to control the smoke caused by the incomplete combustion of the organic constituents of rubber, oil and grease, plastics, paint, cardboard, and paper.

Particulate emissions from secondary aluminum operations were estimated to be 6,000 tons in 1967. Assuming that the 1967 control levels of 60 percent for reverberatory furnaces and 20 percent for sweating furnaces were maintained, emissions would increase to 11,000 tons by FY 1977. The installation of high-efficiency venturi scrubbers on reverberatory furnaces, and fabric filters on sweating furnaces, would allow the industry to achieve the process weight standard. This would reduce FY 1977 emissions to 2,500 tons. The investment cost is estimated to be $28 million with an annual cost estimated at $8 million.

LEAD - Purification in reverberatory furnaces constitutes the most serious air pollution problem in the secondary lead industry. Air is passed through the molten metal to oxidize impurities such as iron, zinc, and antimony. While most of the metallic oxides are removed as a dross from the bath surface, some fine particulate matter escapes with the flue gas.

The reduction of lead oxide in blast furnaces or cupolas is another significant source of air pollutants. The primary emission from this operation is particulate material entrained by the turbulent flow of gases upward through the charge materials (lead, oxide, coke, and limestone).

Because of the toxic nature of lead compounds, the secondary lead producers have achieved a fairly high degree of control. It is estimated that the 1967 level of control was 90 percent, and emissions amounted to 6,100 tons. If this control level was maintained, emissions would grow to 8,200 tons by FY 1977. The process weight code could be achieved by installing fabric filters on reverberatory and blast furnaces which are not already well controlled. This would reduce emissions to 1,600 tons in FY 1977 for an investment cost estimated at $764,000 and annual cost of $150,000.

ZINC - Sweating processes separate zinc from metals having higher melting points and from nonmetallic residues. Sweating, usually conducted in kettle furnaces, reverberatory furnaces, or rotary furnaces, may cause emissions of smoke and oily mists from the combustion of organic material, zinc or zinc oxide particles, other metallic oxides, and the products of fuming fluxes (e.g., ammonium chloride).

Distillation of zinc in retort furnaces purifies the metal and produces powdered zinc or zinc oxide. In this operation, zinc is vaporized in the retort and then passed through a condenser, where it may be either rapidly cooled to below the melting point to produce powdered zinc or slowly cooled to above the melting point to produce liquid zinc for manufacturing slabs. When zinc oxide is produced, the condenser is bypassed and excess air is introduced to both cool and oxidize the zinc vapor; a baghouse is usually employed to collect the oxide. Zinc and zinc oxide fumes are the primary emissions from the distillation and oxidation processes.

Particulate emissions from the secondary zinc industry were estimated to be 800 tons in 1967. If the 1967 control levels of 20 percent for sweating furnaces and 60 percent for distillation furnaces were maintained, emissions would increase to 1,200 tons by FY 1977. The installation of fabric filters on both types of furnaces would achieve the process weight code. This would reduce FY 1977 emissions to 100 tons and would require an investment of $526,000 with an annual cost of $62,000.

c. Scope and Limitations of Analysis

Because many of the firms are small, locally oriented, or subsidiaries of major corporations, data describing several of the characteristics of the secondary metals industries were often lacking. Voids were particularly prevalent in capacity and financial data. For several firms it was not possible to estimate key parameters such as operating ratios and profits per ton of output before and after control.

2. Engineering Basis of the Analysis

a. Copper

Effective control of the reverberatory furnaces in the brass and bronze industry can be achieved through the installation of fabric filters. Cooling equipment must be provided to lower the temperature of the gas stream below the critical point for the glass fabric selected as the filter medium.

Table 4-73 shows a distribution of furnace capacities and the required control efficiency, investment, and annual cost for each furnace size. The Industrial Gas Cleaning Institute Study (Reference 2) was used as the source for cost information. Uncontrolled emissions were estimated at 70 lb. of particulates per ton of metal changed. Depreciation was assumed to be straight line over 15 years, and an interest rate of 10 percent was applied. From Table 4-73, average cost factors weighted by capacity were calculated to be $1273 investment and $246 annual cost per ton of daily capacity.

Production in 1969 was 70,000 tons and is expected to grow at 3 percent annually. It is estimated that 60 percent of the industry is currently controlling to an average level of 95 percent. These assumptions were used to compute the additional investment and annual cost required to bring the entire industry into compliance by 1977.

b. Aluminum

Secondary aluminum is most often refined in reverberatory furnaces. When chlorine is used as a fluxing agent, the evolution of submicron $AlCl_3$ abd Al_2O_3, along with gaseous HCl and unreacted chlorine, requires that a highly efficient wet control system be installed. It is assumed that the system will consist of a cooling chamber, a venturi contactor, and a gas absorption tower using caustic liquor.

Capacity data are available for the 20 largest plants which accounted for some 70 percent of the 1967 industry output of 684,000 tons. Furnace capacities were estimated

TABLE 4-73. CONTROL COSTS FOR BRASS/BRONZE REVERBERATORY FURNACES

Capacity (Tons/Day)	No. Furnaces	Required Efficiency (%)	Investment ($1000)	Annual Cost ($1000)
12	4	93.7	36	7.3
25	3	95.1	50	9.7
30	4	95.4	54	10.4
60	7	96.3	73	13.9
70	4	96.5	78	15.0
75	6	96.6	80	15.5
80	2	96.7	82	15.9

Source: Industrial Gas Cleaning Institute, 1970 for these plants, and this distribution appears in Table 4-74 along with required control efficiencies and the associated costs. Particulate emissions are estimated at 21 lb. per ton of metal reclaimed. Costs were based on information in Reference 2 with the assumptions of straight-line depreciation over a 10-year life and an interest rate of 10 percent. It was estimated that the 68 smaller plants have an average capacity of 20 tons per day, and the same methodology was used to derive control cost estimates for these plants. Twenty-five percent of the reverberatory furnaces are currently controlled to a satisfactory degree. Growth in the industry is expected to average 6 percent per year through 1977.

Aluminum is frequently separated from higher melting materials through "sweating" in reverberatory furnaces with sloping hearths. Particulate emissions from this operation are estimated at 14.5 lb. per ton of aluminum reclaimed. An effective control system for this process consists of an afterburner, U-tube heat exchangers for gas cooling, and a baghouse. It is estimated that there were 18 such furnaces in 1967 with an average capacity of 24 tons per day. Costs for controlling these furnaces were derived from data in Reference 2 with the assumption of 10 percent interest and straight-line depreciation over the 25-year life of the control system.

c. Lead

Reverberatory furnaces are used for sweating, melting, and purification of secondary lead. The most satisfactory device for controlling the particulate emissions from these furnaces is a fabric filter. In most cases it is necessary to cool the gas stream prior to filtration. It was assumed that this would be accomplished with a "U-tube" cooling section followed by a dilution air damper.

TABLE 4-74. CONTROL COSTS FOR SECONDARY ALUMINUM REVERBERATORY FURNACES

Capacity (Tons/Day)	No. Furnaces	Required Efficiency (%)	Investment ($1000)	Annual Cost ($1000)
15	1	63	127	39.6
35	2	72	155	53.8
40	9	73	160	57.0
50	9	75	170	62.8
60	8	76	178	67.6
70	4	79	185	72.5
100	2	80	200	85.5

Capacity data for these furnaces were not available. It was assumed that there were 125 such furnaces in 1967 having an average capacity of 25 tons charge per day. Particulate emissions are estimated at 130 lb. per ton processed. Reference 2 was used as the basis for control costs. Straight-line depreciation over 25 years and a 10 percent interest rate were assumed.

Blast (cupola) furnaces are another significant source of air pollution in the industry. These furnaces are used to reduce lead oxides contained primarily in furnace drosses and slags. An afterburner is normally used to remove carbon monoxide, hydrocarbons, and odors from the exhaust gas. Once again, fabric filters provide the most effective particulate control. Precooling is achieved through the introduction of dilution air.

It was assumed that there were 18 blast furnaces in operation in 1967 with an average capacity of 32 tons charge per day Emissions are estimated at 190 lb. per ton processed. Cost information was obtained from Reference 2. Depreciation was assumed to be straight line over a 10-year life, and the interest rate was assumed to be 10 percent.

Growth in the industry is expected to average 3 percent per year through 1977. It is estimated that 95 percent of the industry capacity is already adequately controlled.

d. Zinc

Zinc is frequently reclaimed from higher melting point metals in reverberatory or kettle-type furnaces. The rate of emissions from this operation depends upon the amount and type of impurities in the feed stock. The presence of carbonaceous material in the effluent usually requires that an afterburner be provided. The remaining particulate emissions may be effectively controlled by a fabric filter installation. It is estimated that 12 lb. of particulates are generated for each ton of metal processed. It was assumed that there were 20 reverberatory furnaces exhausting an average of 8,000 cubic feet per minute of gas each and five combinations of kettle furnaces exhausting 10,000 cu. ft. per minute of gas each in use in the industry in 1967.

The purification of secondary zinc is normally accomplished through distillation in a retort furnace. Although the furnace-condensor combination is normally a closed system, significant quantities of particulates are emitted when scrap is charged or residue removed. Satisfactory control of these emissions is achieved with a fabric filter. The emission rate is estimated at 45 lb. per ton of metal processed. It was assumed that in 1967 there were 10 banks of 10 retort furnaces in the industry, each bank requiring 10,000 cu. ft. per minute of exhaust gas.

Fabric filter installation and annual costs were derived from Publication No. AP-51 (Reference 7). It is expected that the industry will experience a 4 percent annual growth rate through 1977.

3. Industry Structure

a. Characteristics of the Firms

COPPER - The secondary copper industry may be divided into two segments: (1) Brass and bronze manufacturers account for most of output--60 plants produce brass and bronze ingots and 125 brass mills produce copper alloy sheets, rods, plates, and tubing; in 1967, brass and bronze manufacturers produced 898,000 tons of copper-based alloys. (2) Secondary smelters refine scrap back into unalloyed copper. They tend to be small, independent operators and often reclaim other metals as well as copper; in 1967, these produced 63,000 tons of refined copper.

ALUMINUM - The secondary aluminum industry is commonly divided into three sectors: (1) Secondary smelters generally process scrap to ingot form, which is then sold to fabricators. Comprising by far the largest portion of the industry, secondary smelters normally refine around 70 percent of total processed scrap. For 1969, these companies accounted for 708,000 tons of the total reported 1,057,000 tons of scrap consumed. (2) Nonintegrated fabricators, the second largest group, normally process 15 to 17 percent of the scrap supply; for 1969, these accounted for 151,000 tons of the total reported scrap consumed. (3) The primary aluminum industry itself processes scrap generated from its own operations and accounts for the remaining 13 to 15 percent of total scrap consumed.

For the base year 1967, the secondary aluminum industry was represented by 73 firms and 88 plants, excluding primary producers. Of the 88 plants, 30 are strictly aluminum smelting operations, and the remainder have only minimal interests in this particular metal. Eight companies control most of the capacity and are considered to be the major smelters.

LEAD - The secondary lead industry is normally divided into two sectors: (1) Primary lead refiners use a small amount of scrap as raw material input; for 1967, these consumed only 2 percent of the total reported scrap and produced about 10 thousand tons of secondary metal. (2) Secondary smelters and remelters processed 98 percent of consumed scrap in 1967 and produced nearly 544,000 tons of secondary lead with 235 firms and 268 plants; only 32 firms (owning 65 plants) are of significant size, with the remainder being small, local firms of under 20 employees or having minimal interests in lead. Two of the large firms control 33 plants and almost 50 percent of the secondary capacity.

ZINC - The secondary zinc industry is composed of 12 firms and 15 plants. Most of the firms process other metals as well as zinc. Five of the plants produce zinc dust only, while the remainder produce a mixture of slab zinc, zinc dust, zinc oxides, and zinc alloys. In 1967, the industry produced a total of 73,000 tons of zinc products.

b. Operating Characteristics

COPPER - As the supply of recoverable scrap has grown, capacity in secondary smelters (for producing unalloyed copper) has increased accordingly. Most of this expansion has been through the addition of new furnaces in existing plants, rather than the entry of new firms into the industry. The operating ratio in this segment of the industry is high, probably approaching 90 percent.

Brass and bronze production is more directly related to the demand for copper alloy products than to the supply of copper-based scrap. Since World War II, there has been little increase in capacity for this segment of the industry. The operating ra is estimated at 80 percent.

ALUMINUM - Complete capacity data for the aluminum industry is unavailable and operating ratios cannot be calculated. However, the industry normally operates at healthy rates. Markets have been favorable. The scrap supply has grown rapidly. The industry has expanded greatly over the past decade. Growth in recent years has been chiefly through enlargement of existing plants rather than the building of new ones; the trend has been larger reverberatory furnaces, with capacities ranging up to 100 short tons of aluminum per day. The industry is technologically advanced and is able to maintain a high degree of control over alloy content, impurities, and heat.

LEAD - Major producers of secondary lead normally operate in the range of 85 to 90 percent of smelting capacity. Production is cyclical, depending on final product need and the health of the economy, but it fluctuates less than primary production. Unlike many other secondary metal industries, the secondary lead industry normally accounts for over half of the domestic lead production and has a substantial influence on market trends. These firms are well integrated and use much of their production in the fabricating of final consumer products. In times of strong demand, secondary producers call on primary producers to supply lead for fabricating operations; when demand slackens, secondary producers can supply a much greater percentage of their own fabricating needs.

ZINC - Complete capacity data for the zinc industry are not available. It was therefore difficult to determine operating ratios accurately, but it is assumed that they are quite low, probably close to 70 percent. During the past few years, little new capacity has been added. Production rates (particularly for redistilled slab zinc) have declined, due mainly to a shortage of scrap suitable for reclaiming.

c. Resources

COPPER - Copper-bearing scrap is usually classified as either new or old. New scrap refers to newly manufactured materials--drosses and residues from smelting processes as well as turnings, clippings, punchings, and defective articles from fabrication operations. In 1967, new scrap accounted for 56 percent of total scrap copper consumption. Old scrap consists of obsolete, domestic, and industrial products of high copper content; examples include copper wire, cable, pipes, valves, radiators, and ship propellers.

Brass and bronze manufacturers purchase most of their scrap through dealers who classify it by type and provide an approximate chemical analysis of each lot. Major raw materials of these manufacturers include primary copper (10 percent of the total copper in their products), zinc, tin, lead, and other alloying constituents as well as fuel oil or natural gas.

ALUMINUM - Aluminum scrap is also classified as new and old. New scrap, a byproduct of current fabricating operations, includes borings and turnings, clippings and forgings, and residues from various melting operations. Major suppliers are the aircraft, automobile, aluminum fabricator, and primary aluminum industries. New scrap accounts for approximately 85 percent of the smelter's mix. Old scrap comes from used or outdated products; examples are dismantled automobiles, household appliances, junked airplanes, scrap aluminum foil, wire and cable, and beverage cans. The availability of old scrap is expected to increase or maintain its percentage (15%) of the smelter's supply. Both types are normally gathered by dealers, who segregate and bale it and then ship bulk loads to the secondary smelters. For 1967, reported scrap consumption by secondary producers amounted to 883,000 short tons (760,000 tons if consumption by primary producers is excluded).

Fuel consumption, a major cost input, is natural gas or fuel oil, depending on economic conditions and availability. Estimates of fuel consumption vary in the literature but seem to range from 4 to 7 million Btu's per short ton of metal treated. Variances may be explained by the melting properties of the different alloys being formulated. For aluminum, the low melting point (1220°F) and high thermal conductivity imply easy melting; however, it is an excellent reflector of radiant energy--a property that hampers thermal transfer in reverberatory type furnaces. Fuel efficiency for melting is considered good at 30 percent of input.

LEAD - Because lead has a high resistance to corrosion, it readily lends itself to reclamation through scrap processing. Lead scrap, like copper and aluminum scrap, may be classified as new and old. New scrap is a byproduct of current fabrication operations; for 1967, lead oxide drosses and residues from manufacturing and foundry sources amounted to 101,000 tons of new scrap. Old scrap comes from obsolete or wornout products--batteries, cable coverings, piping, type metal, solder, common babbit, and lead sheet; in 1967 electric storage batteries were the major source, 73 percent of the 625,000 tons of old scrap.

Although products such as tetraethyl-lead gasoline additives and paint pigments are not recoverable, it is estimated by the Bureau of Mines that roughly 50 percent of consumed lead can be reclaimed and that recoverable lead-in-use has increased to over 4 million tons to provide adequate supply.

ZINC - The extensive usage of zinc in galvanizing and in compounds in which the metal is lost has limited the availability of zinc suitable for reprocessing. Scrap is again classified as new and old. New scrap which accounts for about 75 percent of the total consumption, consists primarily of skimmings and drosses from galvanizing operations, clippings, and chemical residues; old scrap includes die castings (chiefly from dismantled automobiles), rod and die scrap, used dry cells, engraver plants, and other rolled zinc articles. Most old scrap is purchased by the secondary producers from dealers. In some cases, the dealer will concentrate the zinc content through sweating prior to shipment to the secondary plant.

4. Market

a. Distribution

COPPER - Both the secondary smelters and the brass and bronze manufacturers tend to locate in metropolitan areas primarily in the Northeastern, Pacific Coast, and East North Central States. This places them in close proximity to both the largest sources of scrap and the major outlets for their products.

Copper-base alloys are characterized by high strength, workability, and corrosion resistance. Because of these properties, brass and bronze are widely used in the production of hardware, radiator cores, condensers, electrical equipment, ship propellers, and many other devices. Production by form of secondary recovery of copper for 1967 was as follows:

Alloy Type and Other Forms	Copper Recovered (Short Tons)
Unalloyed Metal (Secondary producers only)	63,337
Brass and Bronze Ingots	311,892
Brass Mill Products	531,139
Brass and Bronze Castings	54,342
Brass Powder	978
	961,688

ALUMINUM - Although primary producers tend to locate near cheap power sources, secondary aluminum producers generally cluster in the heavily industrialized areas--chiefly near Los Angeles, Chicago, Cleveland, and New York to Philadelphia. These locations provide good proximity to suppliers of scrap as well as to the market.

Secondary producers sell to a limited market, primarily casters of the metal. Approximately 90 percent of secondary output is consumed by the casting industry, which in turn depends upon secondary smelters for the major portion of its raw materials. Secondary producers supply 70 to 80 percent of all of the aluminum used by the casting industry. Primary producers supply the remainder. For 1967, about 698,000 short tons of aluminum were recovered from scrap. Output by type of alloy is as follows:

Alloy Type and Other Forms	Aluminum Recovered (Short Tons)
Unalloyed Metal	53,656
Aluminum-Based Alloys	628,848
Brass and Bronze	643
Zinc-Based Alloys	8,304
Magnesium Alloys	1,195
Chemical Compounds	5,105
	697,751

LEAD - Most secondary lead producers are in metropolitan areas throughout the country, with ready access to sources of scrap and to the marketplace. In contrast, primary lead smelters are generally near sources of lead ore to minimize transportation costs from mine to mill.

Storage batteries for home, leisure, industrial, and automotive purposes are by far the largest single use for lead. Most important, virtually all battery manufacturing plants are operated by major secondary lead producers. For 1967, this product class accounted for 37 percent of total U.S. lead consumption, a ratio which has been on the rise. Although a rather cyclical market, depending to a large degree on new car production and the number of total vehicles on the road, battery consumption has proved to be one of the two major growth areas for the entire lead industry. By 1969, battery usage of all types was about 42 percent of U.S. lead consumed.

Typically, a secondary firm manufactures a broad line of industrial and commercial batteries. Most of the output is sold to oil and tire companies and mass merchandisers for resale under private labels, although a substantial amount is sold under proprietary brand names of the original manufacturer. Two-thirds to three-fourths of all batteries are sold in the replacement market.

Lead alkyl manufacture (production of tetraethyl and tetramethyl lead for use as gasoline antiknock agents) has been the other major growth area for lead metal. No secondary producers manufacture lead alkyls per se, although they probably do supply small amounts of lead raw materials to chemical concerns which do manufacture these products. Thus if environmental concerns lead to the curtailment of lead additives, the secondary lead industry would be directly affected to a minimal extent.

Other markets for secondary lead include paint pigments, bearings, brass and bronze alloys, type, solder, piping, and cable covering for the construction, transportation, printing, and communication industries. The lead content of these products accounts for 40 percent of secondary production. Sales in these areas show cyclical patterns and on the average have shown small downtrends over the past several years.

ZINC - Secondary zinc smelters are primarily located in metropolitan areas of the Northeastern, Pacific Coast, and East North Central States. The major consumers of zinc are the iron and steel industry (galvanizing); the automobile industry (die castings for carburetors, grilles, trim, etc.); the brass and bronze industry (alloying constituent); the rubber and industrial chemical industries (pigments and compounds); and the manufacture of dry cells and lithographic plates.

b. Competition

COPPER - The quality of secondary copper, reclaimed as unalloyed metal, is in no way inferior to that of primary copper. Secondary smelters compete directly with the primary producers. In contrast, the majority of the end products made of brass and bronze requires the unique properties of these alloys either in the machining process or in the final application. Little substitution is likely in the traditional outlets for brass and bronze manufacturers, if price increases should occur.

ALUMINUM - The term "secondary" refers not to excellence or quality but to origin and is generally defined as "aluminum which has lost its original identity as to source."

Because their prices are normally lower than those of primary producers, secondary producers supply most of the casting alloys. They also have gained favor by doing custom tailoring for their customers. Primary and secondary producers do compete for sales of hot metal and aluminum slot and notch bar for destructive uses, but these markets are not particularly significant for either.

The secondary producers do not face direct external competition in the form of substitute products, except in the general sense that aluminum does compete with other materials such as copper, steel, and plastics. Secondary smelters are, however, dependent upon the fortunes of the casting industry, which has shown dramatic growth over the past decade in the markets that are very broad; major customers include the transportation, machinery, defense, home appliances, office equipment, and photographic industries.

LEAD - The secondary lead industry faces a mixed pattern of external competition in the form of substitute materials. The most significant market, batteries, would not be threatened in the short term. Several combinations of alternate materials, such as nickel, zinc, silver, cadmium, and mercury, can provide stored electric energy; however, most of these are limited in quantity or electrical characteristics and at present are not considered viable substitutes to meet the large volumes required for transportation and industrial power requirements. Manufacturing efficiencies and technological improvements, including improvements in battery life, have maintained the superior position of lead-based power storage.

Other product areas face stiffer competition: (1) Lead continues to hold its market in structural and highway painting, but lead-based pigment for paint manufacture has not been a growing market; development of substitutes has advanced rapidly, particularly those for interior and exterior house paints. (2) Products for the construction sector, an area in which lead has had much historical significance, have faced strong competition; that is, sales of piping, lead calking, and sheet lead have been on the downtrend because of substitutions from plastics, stainless steel, ceramic products, and plasterboard. (3) Demand for lead as type metal in the printing industry has shown a slight decline in recent years due to technological shifts, particularly with regard to new photographic methods. (4) Use of lead for cable covering in the communications industry has been slowly receding, as alternate materials, principally plastics, have been introduced. (5) Lead packaging in the form of collapsible tubing, foil, and solder has shown a level demand pattern because of substitutive techniques and materials such as plastics, tinplate, and paper.

ZINC - Zinc has several unique properties that make it particularly suitable for many applications: its resistance to corrosion makes it useful for the galvanizing of iron and steel, its low melting point makes molds or dies last longer, its hardness is required in brass, and its ductility is suited for rolling or drawing. Nevertheless, zinc competes with ceramic and plastic coatings for anticorrosion applications; with aluminum, magnesium, and plastics in die casting; and with titanium pigments in the paint and ceramics industries.

5. Trends

COPPER - Production and prices for secondary copper are related to the historical fluctuations inherently found in the copper industry as a whole. Total secondary copper recovered in alloy form grew from 571,000 short tons in 1960 to 737,000 short tons in 1967, for a growth rate of 3.7 percent per year. Output was cyclical, with bottoms shown in 1961 and 1966 and a peak at 790,000 short tons in 1965. Due to uncertainties in the supply and demand for all copper, intermittent labor disputes, and probable slackening in demand for defense purposes, growth in secondary copper is estimated at 3 percent through FY 1977.

ALUMINUM - Recovery of secondary aluminum set a new record every year from 1960 to 1969--a period when production grew from 329,000 to 850,000 short tons, for a healthy growth rate of 11 percent per year. Operations for the past 2 years have been sluggish because of the general downward trend of the economy and the consequent lessening in demand for castings; the longterm future for castings appears favorable, however, and the demand for secondary a aluminum should grow at a rate of approximately 6 percent through FY 1977. Average prices for secondary aluminum, in cents per pound, for the period 1960-69 compare with those for primary aluminum as follows:

	1962	1963	1964	1965	1966	1967	1968	1969
Primary	23.9	22.6	23.7	24.5	24.5	25.0	25.6	27.2
Secondary	21.2	21.3	22.3	24.3	24.7	24.3	25.5	26.8

LEAD - Production of secondary lead increased from 453,000 short tons in 1961 to 604,000 in 1969 for a yearly growth rate of 3.7 percent. Demand for storage batteries contributed substantially to the upward trend, while other product areas showed relatively level or slightly declining output. Production trends in the automobile industry are important as lead is a major component in original and replacement equipment. A growth rate of 3 percent is expected for secondary lead production through FY 1977. Prices generally follow those of primary lead, but are somewhat obscure because of the captive nature of secondary output for further fabrication.

ZINC - Secondary zinc output rose from 57,000 short tons in 1963 to 73,000 in 1967 for a yearly growth rate of 5.0 percent. A growth trend of 4.0 percent is expected through FY 1977. Gains reflect the upward trend in the economy, particularly in the automobile industry. Zinc prices fluctuate chiefly due to heavy reliance on the automotive and construction industries, but the swings normally have not been severe--between 11.5 and 15.5 cents per pound over the past decade.

6. Economic Impact of Control Costs

a. Impact on Plant

Operating statements for model plants within the secondary metal industries were not developed because of the lack of sufficient financial information. Many are small, family-controlled operations; others are owned by large metal conglomerates. Without more detailed information, it was not possible to estimate accurately the appropriate revenues, costs, and profits. As an approximation of the impact of compliance with standards, the average costs per unit of output have been developed and are shown in Table 4-75. As shown, secondary aluminum faces by far the highest control cost per unit of output and, consequently, the greatest potential impact of the four metals.

TABLE 4-75. AVERAGE COST OF CONTROL--SECONDARY NONFERROUS METALS

Industry	Average Price/ Short Ton (1969)	Control Cost/ Short Ton	Percent of Price
Copper	$960	$0.54	0.1
Aluminum	$530	$6.34	1.2
Lead	$298	$0.21	0.1
Zinc	$292	$0.59	0.2

b. Demand Elasticity and Cost Shifting

Secondary copper smelters compete with primary producers and are subject to the cyclical nature of the copper industry as a whole. However, both the primary and the secondary sectors are expected to pass on the added costs of pollution control in the long run. Supporting this conclusion are the facts that control costs for secondaries are minimal, in absolute terms and in comparison to those of the primary producers. Assuming full implementation, secondary copper producers should actually have greater competitive advantage; comparative costs are 3.2 cents per pound for the primary producers and 0.03 cents per pound for the secondary copper producers. For secondary lead and zinc producers cost increases are minimal for each in the absolute sense and with respect to primary producers.

Secondary aluminum faces an average control cost of 0.3 cents per pound, which is well below primary costs, at 2.4 cents per pound. This implies that secondary producers will be able to maintain their prices below primary metal prices even if costs are passed on to their customers, and in turn will be able to maintain their market in providing ingots for the aluminum casting industry. With a favorable longterm outlook for castings and mild external competition, secondary aluminum producers should be able to pass on the costs.

c. Effect on Industry

All four secondary nonferrous industries contain a great number of small firms--over half of them with fewer than 20 employees. For the 10 percent that operate close to the break-even point, control costs could be relatively more severe and could cause a few firms to drop out of the market. In general, however, air pollution control should have little impact on the structure and the competitive patterns of these secondary industries because of the small cost burdens involved.

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P. Sulfuric Acid

1. Introduction

a. Nature of Product and Process

Sulfuric acid is the largest single chemical product in the United States. It is used in the production of phosphate fertilizers and other industrial chemicals, in the purification of petroleum, the leaching of copper ore, and the pickling of steel.

Almost 97 percent of all sulfuric acid is produced by the contact process. Generally in this process, sulfur or pyrite is burned to form sulfur dioxide (SO_2) which is then catalyzed to sulfur trioxide (SO_3). Sulfur trioxide is absorbed in sulfuric acid to form more concentrated grades of sulfuric acid and oleum. An increasingly important source of sulfur dioxide is that liberated during the smelting of sulfide ores bearing copper, nickel, zinc, and lead. The final 3 percent of acid is produced by the obsolete and costly chamber process, but because this process is rapidly being phased out, it will not be emphasized in this analysis.

b. Emissions and Cost of Control

Pollutants consist of sulfur dioxide escaping catalytic conversion and acid mists emitted from the absorption tower. Most plants today operate with a single absorption step resulting in a sulfur dioxide to sulfur trioxide conversion of 96 to 98 percent. Compliance with the assumed emission standard requires upgrading the conversion efficiency to 99.5 percent or tail gas scrubbing with alkaline solutions. (New acid plants are expected to achieve 99.7 percent conversion efficiency.) This would result in a reduction of 86 percent from the existing emission level of a typical acid plant. To accomplish 99.5 percent conversion requires partial removal of the sulfur trioxide formed, via primary absorption, which improves the oxygen-to-sulfur dioxide ratio for favorable conversion of the residual sulfur dioxide. Secondary absorption is required to complete the recovery of sulfur trioxide as acid.

Due to the high cost and technical difficulties of converting an existing single absorption plant to dual absorption, the latter method will probably not be used for control of existing facilities. However, its application to new contact process acid plants is considerably less costly than tail gas recovery methods. Hence, this study reflects use of dual absorption for new facilities and tail gas recovery methods for existing facilities.

Acid mists are produced due to the presence of residual water from incomplete drying of the air feed to the sulfur burner or due to the impurities that liberate water during the combustion in the sulfur burner. The water combines with the sulfur trioxide in the absorption tower to form fine acid mists which escape in the tail gas unless captured by a mist eliminator.

For 1967, the industry emitted 600,000 tons of sulfur dioxide and 25,000 tons of mist particulates. Without the implementation of the Act, emission levels in FY 1977 would increase to 920,000 tons of sulfur dioxide and 38,000 tons of acid mist. Implementation of the Act will reduce these levels in FY 1977 to 170,000 tons of sulfur dioxide and 10,000 tons of acid mist. The demand for sulfuric acid is expected to grow at an annual rate of 3 percent.

In order to control these emissions, the industry will have to invest $169 million in controls and $39 million in annual costs by FY 1977.

2. Engineering Basis of the Analysis

The emission of sulfur dioxide is dependent upon the degree of conversion of sulfur dioxide (SO_2) feed to sulfur trioxide (SO_3) in the catalytic converter. The chemical reaction kinetics dictate that the conversion depends upon the oxygen to sulfur dioxide ratio in the converter feed gas. Other factors for emission formation include the rate of acid production, quantity of catalyst used, and feed temperature in the final catalyst stage. Most standard contact plants in operation today using the single absorber can vary in conversion efficiency from 94 to 98 percent.

Acid mists are formed as a result of hydrocarbon impurities in the sulfur feed material, especially in elemental sulfur-based plants. Combustion of these hydrocarbons in the sulfur burner produces water which combines with SO_3 to produce very fine mists particulates. Acid mists are particularly a problem with oleum production, where 80 to 95 percent by weight of the mists particles are smaller than 2 microns in diameter. This situation presents an opacity problem for the tail gas. For plants producing acid of 98 percent strength, only 30 percent by weight of the mists particles are smaller than 2 microns.

The emission factors for determining the control level and requirements under the assumed standards for sulfur dioxide and particulates are as follows:

	SO_2	ACID MISTS
Uncontrolled Emissions, pounds per ton (100%) acid	60	(a) 4.0 (nonoleum) (b) 6.0 (oleum)
1967 Emission Rate, pounds per ton	43	1.8 (oleum and nonoleum)
Allowable emissions, pounds per ton (100%) acid	6.5	0.5 (oleum and nonoleum)

Investment and annual control costs were developed from a comprehensive cost engineering study performed by the Chemical Construction Corporation for the sulfuric acid industry to meet requirement in Air Quality Control Regions. The cost data were corrected to 1970 dollars. Cost requirements for control of sulfur dioxide via dual absorption are shown in Table 4-76. Investment costs include an absorption tower, a converter stage, coolers, blower, pump, tank, and piping. Additional heat to bring the reaction mixture up to reaction temperature for the second converter (added to base plant and included in investment) is supplied by the sulfur furnace. Tail gas scrubbing systems for removing SO_2 are an acceptable alternative to dual absorption and are considered in the economic analysis later in this section.

The abatement strategy for control particulates included dual mesh pads for nonoleum plants and tubular fiber demisters for oleum plants. Investment and annual costs for mesh pads and tubular demisters are shown in Tables 4-77 and 4-78, respectively.

The size distribution of plant capacity for determining pollution control costs is shown in Table 4-79. These plants represent non-smelter acid plants that are assumed to be faced with controlling SO_2. Smelter acid plants would be allowed to maintain their existing performance under the assumed abatement strategy for the primary non-ferrous metals industry. However, control costs would be required for acid mists. Again, dual mesh pads and tubular fiber demisters were assumed to be required with the same rationale as for the contact acid plants.

TABLE 4-76. SULFURIC ACID EMISSION CONTROL COSTS: DUAL ABSORPTION

Plant Size (100% H_2SO_4, tons/day)	Costs ($1,000)	
	Investment	Annual*
50	312	68.2
250	578	133.1
750	1104	249.7
1500	1740	434.2

*Without supplementary production of acid

TABLE 4-77. SULFURIC ACID EMISSION CONTROL COSTS: MIST ELIMINATORS*

Plant Size (100% H_2SO_4, tons/day)	Costs ($1,000)	
	Investment	Annual
50	15.6	2.2
250	30	6.8
750	42	6.4
1500	57.6	6.9

*Dual wire or Teflon mesh pads

TABLE 4-78. SULFURIC ACID EMISSION CONTROL COSTS: MIST ELIMINATORS*

Plant Size (100% H_2SO_4, tons/day)	Costs ($1,000)	
	Investment	Annual
50	93.6	23.7
250	120	31.2
750	180	48.1
1500	288	57.2

*Tubular fiber demisters for oleum plants

TABLE 4-79. PLANT CAPACITY SIZE DISTRIBUTION FOR SULFURIC ACID INDUSTRY*
DECEMBER 31, 1969

Daily Capacity, Tons	Nonoleum Plants, No.	Plants with Oleum Facilities, No.
0-150	36	9
151-250	20	10
251-500	30	23
501-750	18	5
751-1000	11	4
1001-1500	9	4
1501-2000	5	2
>2000	2	0
TOTALS	131	57

*Excluding smelter acid plants

3. Industry Structure

a. Nature of the Firms

In 1967, there were 254 sulfuric acid plants owned by 94 firms. Their combined capacity was 38 million tons. Of the total number of plants, 213 were contact process plants and 41 were chamber process plants. Of the total contact process plants, 24 were smelter acid recovery operations. Chamber process plants are predominantly small, ranging in capacity from 40 to 100 tons per day, while contact process plants range from 10 to almost 5,000 tons per day.

Total acid output for 1967 was 29 million tons, of which only 13.5 million tons were shipped. The difference between production and shipments indicates the extent to which acid production is "captive" and serves as an intermediate product within the same establishment. Most sulfuric acid plants are owned by sulfur producers, chemical companies, petroleum refineries, fertilizer plants, and smelters which use some, if not all, of their production internally for the production of their final product. Of the acid shipped, 90 percent was sold commercially. The remainder was interplant transfers.

b. Resources

The raw material consumed in sulfuric acid production is elemental sulfur, smelter or refinery waste gas, spent acid, acidic sludge, and pyrites. In all but the first case the raw material is a necessary byproduct and can, therefore, be considered free for the production of acid.

Elemental sulfur is produced largely from mines on the gulf coasts of Texas and Louisiana. Considerable amounts of sulfur are also produced from operations which find it economical to recover elemental sulfur rather than produce acid directly. Sources of recovery include waste gas streams of coke oven processes and petroleum refineries.

Most of the recoverable sulfur is converted directly to acid due to the higher costs of processes for recovering elemental sulfur from most sources. Sulfur dioxide in smelter stack gases is increasingly being recovered in the form of acid as an air pollution control measure.

Similarly, hydrogen sulfide emitted by petroleum refineries is recovered and burned to produce sulfur dioxide and subsequently either elemental sulfur or acid. Also, large quantities of acid used in the refining process are recovered from acidic sludge since the sludge cannot be discharged into streams or disposed of economically. This sludge is also burned to sulfur dioxide.

Processes are under development for the recovery of sulfuric acid or elemental sulfur from sulfur dioxide emissions in electric power plant stack gases. Such processes will not reach wide commercial application for at least 5 years and thus will have little impact on the supply or price of sulfur before that time.

The final major source of sulfur, pyrites (sulfur-bearing impurities in coal), are removed by coal-cleaning processes, then roasted to emit sulfur dioxide. This source of sulfur amounts to approximately 4.5 percent of the U. S. production of sulfuric acid.

Of far greater immediate significance is the flood of low-cost sulfur which has entered the United States market from Canada, driving the price down from $38 per ton in 1968 to only $18 per ton in 1971. The sulfur has been removed from sulfur-laden natural gas as a byproduct in order to meet the air pollution control requirements of the U.S. fuel markets. U.S. sulfur-mining companies have been forced to drastically cut back production, halt exploration, and lay off employees.

The displacement of most U.S. sulfur-mining is inevitable even without imports. More sulfur is emitted into the air each year than is consumed in the United States. Air pollution laws requiring the recovery of most of this sulfur will result in the domestic recovery of sufficient byproduct sulfur and acid to meet demands.

4. Markets

a. Major Markets

Phosphate fertilizer production accounts for approximately 40 percent of all sulfuric acid consumed in the United States. An additional 8 percent is used in the manufacture of ammonium sulfate, which is also used extensively in fertilizer manufacture.

Since the early sixties, the utilization of highly concentrated superphosphate fertilizer has increased rapidly, displacing normal phosphate. Disproportionately greater quantities of sulfuric acid are required for production of superphosphate than were required for production of normal phosphate. The demand for sulfuric acid by the fertilizer industry has, therefore, grown even more rapidly than the demand for fertilizer itself. Although fertilizer demand has slowed since 1968, the industry's consumption of acid is expected to grow at an annual rate of 5 percent.

The petroleum industry reclaims a large portion of its own spent acid, and therefore relies only partially on outside sources for acid. Compared with sulfuric acid's use in fertilizers, the remaining markets are quite small. Of the latter, petroleum refining is the largest single end-user, accounting for 8 percent of consumption, and the use of acid for this purpose is expected to experience little growth. The use of sulfuric acid in the manufacture of pigments also amounts to about 8 percent of consumption; however, this market is expected to decline to only 4 percent by 1975. The only rapidly growing segment of the market is the leaching of copper ores, which is expected to grow at a rate of 16 percent. Yet, as recovery of acid by smelters increases, this demand will be met by internal production and will, therefore, contribute little to the open market demand for acid. Other major markets, the production of fabrics, hydrofluoric acid, and steel pickling, account for between 3 and 6 percent of consumption.

The majority of commercial acid sales are under long-term contractual agreements and at prices considerably below the published market spot price. For large volumes, these prices may be as low as one-half to two-thirds of the published price. Only small consumers must pay the open market price.

b. Competitive Products

In most of its markets, there are substitutes for sulfuric acid; however, because they are either economically or technologically inferior to sulfuric acid, they have not significantly penetrated the market. In the manufacture of phosphate fertilizer, nitric acid is a technological substitute but it is considerably more costly. Substitution of phosphoric acid for sulfuric as an acidulating agent in fertilizer production has been offset by the use of sulfuric acid in treating phosphate rock to produce phosphoric acid.

The only market sector in which sulfuric acid is being displaced is steel pickling. Hydrochloric acid's superior pickling and easier treatment (after use in the pickling process) qualities outweigh, at least for the present, the lower price advantage of sulfuric acid.

c. Competition Among Sellers

The relative competitive advantages of the various sulfuric acid processes are variable, depending primarily on the prevailing prices of sulfur. Even for a given process, there is considerable variation in cost between individual plants--costs vary with size, age, and plant design as well as the type of sulfur feed stock used. Production costs for conventional sulfur-burning contact process plants vary from $10 to $20 per ton of acid, while costs for smelter acid recovery vary from $4 to $25 per ton. In conventional plants,buying sulfur is the major cost; therefore production costs vary with the price of sulfur. For a typical 1,000-ton-per-day contact process plant, the total cost of acid production would vary from $14 per ton to $7 when sulfur prices varied from $38 per ton to the current price of $18. In contrast, the sulfur raw material from recovery operations is free, yet the capital equipment necessary to recover it from waste gas streams results in a fixed investment of 2 to 5 times that of a contact plant.

Production cost is critical to conventional plants. They will not produce acid if prices fall below variable costs. If the industry were comprised primarily of conventional plants, overcapacity would soon be rationalized and a balance of supply and demand would be achieved at a reasonable profit level. However, the advent of many sulfur dioxide recovery plants in the market has changed competition considerably. Recovery plants must continue to operate at full capacity, regardless of market price, to conform to air pollution control regulations. They, therefore, dispose of acid at any obtainable price and might go so far as to sell at a zero dollar price and even to subsidize transportation costs to the extent of alternative disposal costs. Conventional plants can, therefore, compete with recovery plants only when they are outside of the shipping radius of the recovery plant. Fortunately for the conventional sulfuric acid producers, most recovery plants are now associated with smelters in the Western States, quite remote from the large eastern and midwestern markets.

Transportation cost is obviously an important element in the competitive pattern within the industry. The bulk of sulfuric acid is so great relative to price that shipping costs are exorbitant. It is usually impossible to sell acid profitably beyond a radius of 150 miles if shipments must be made by rail. Barge shipments, where possible, would permit somewhat greater shipping distances.

Economics of scale attainable from large plants are also quickly overcome by transportation costs in commercial markets. The high cost of shipping permits a wide range of plant sizes to operate throughout the country; small plants generally serve remote or captive markets.

5. Trend

The sulfuric acid industry is so closely tied to the market for sulfur and phosphate fertilizer that the three must be examined simultaneously. In the early sixties, both the sulfur and sulfuric acid industries experienced excess capacities. With rapid increases in the demand for superphosphate fertilizers came increases in the demands for sulfur and sulfuric acid. Not until 1965 did demand overtake supply and cause actual shortages. At that time, the price of both sulfur and sulfuric acid began to rise rapidly—sulfur prices from $25 per ton in 1965 to $38 in 1968, and sulfuric acid prices from $26 per ton to $35.

Since 1968, the growth in demand for fertilizers has slowed, as has the demand for sulfur and sulfuric acid. Yet, high prices and correspondingly high profit rates have encouraged the development of excess capacity in each industry. Capacity utilization in the sulfuric acid industry has declined from 95 percent in 1965 to less than 80 percent in 1969. The excess supply has driven gulf coast prices from their high of $35 to $31 per ton in 1971.

The aggregate demand for sulfuric acid is expected to grow at an annual rate of 3 percent during the 1970-77 period. This demand can be absorbed by existing capacity and new smelter acid recovery plants.

Addition of acid plants to copper, lead, and zinc smelters will add 5 million tons of acid production capacity to the 38-million-ton capacity existing at the end of 1969. Acid consumption is expected to reach 43 million tons in 1977. Incorporation of the new smelter capacity will allow the industry to meet demand operating at only 88 percent of capacity. As only moderate profits are earned at this operating rate, no further additions to capacity are expected before 1977. Any new plants constructed before that time will represent replacements of existing capacity due to obsolescence or shift in demand patterns and will, therefore, not increase the total cost of pollution control incurred by the industry. Since most new plants will be larger and controlled by dual absorption, the control costs will actually be less than would be required to implement gas cleaning in existing plants.

6. Economic Impact of Control Costs

a. Impact on Plants

Only sulfur-burning contact process acid plants are considered in this analysis. The economic impacts of sulfur recovery are presented in the analyses of the individual industries concerned.

A major determinant of economic impact on a plant is size. Larger plants realize considerable economics of scale over small plants, both in production and in air pollution control costs. The unit production cost for a standard 1,500-ton-per-day plant is 23 percent less than the cost for a 250-ton-per-day plant, given the same raw material cost.

Table 4-80 presents the financial impact of an investment in air pollution control on two typical sulfuric acid plants--one representing a small 250-ton-per-day plant and the other representing a larger 1,500-ton-per-day plant. For each model plant, an acid price was selected which would approximate the contract or transfer price that might be obtained by that plant in the current depressed market. The table presents operating results for standard plants without pollution control with the results for identical plants controlled by tail gas recovery systems and new dual absorption plants of the same capacity.

TABLE 4-80. MODEL SULFURIC ACID PLANTS

	250 Tons/Day			1,500 Tons/Day		
	Standard Plant	Tail Gas Recovery[1]	New Dual Absorption	Standard Plant	Tail Gas Recovery[2]	New Dual Absorption
Capacity	82500	82500	82500	495000	515000	495000
Production	82500	82500	82500	495000	515000	495000
Fixed Investment	1320	1320	1800	3600	3600	5100
Working Capital	264	264	264	720	720	720
Control Investment	0	342	N/A	0	1900	N/A
Net Investment	1584	1926	2064	4320	6220	5820
Sales	1650	1650	1650	7920	8240	7920
Cost of Goods Sold	1327	1327	1429	6166	6166	6409
Control Cost	0	211	N/A	0	691	N/A
Income Before Tax	323	112	221	1754	1383	1511
Income Tax (50%)	161	56	110	877	691	755
Net Income	162	56	111	877	692	756
Cash Flow	294	222	291	1237	1210	1266
Selling Price[3] ($/Ton)	20	20	20	16	16	16
Control Cost ($/Ton)	0	2.56	1.24	0	1.34	.49
Control Cost (% of Sales)	0	12.8	6.2	0	8.4	3.1
Decrease in Earnings (%)	0	65	31	0	21	14
Rate of Return	13	2.5	6.8	26	15.5	22.5

[1] Assumes lime absorption. No additional acid is recovered.

[2] Assumes control by the Wellman-Power Gas sodium sulfide process. Sales reflect acid recovery.

[3] Approximation of the bulk contract price attainable by each plant size.

Installation of a tail gas recovery system for control of the 250-ton-per-day model plant reduces earnings by 63 percent. Since earnings represent less than half of the cash flows of such small firms, cash flows are reduced less severely than earnings. However, the increased investment for control, coupled with reduced cash flows, reduces the rate of return far below attractive levels. Many small plants will be forced to consider closing rather than implementing controls. It becomes advantageous for a plant to close if the present value of its potential cash flows is less than the sum of the control investment, salvage value, and the tax writeoff attainable from closing the plant. With such low cash flows after control, few plants of 250 tons per day or less will find it economical to continue operation.

The dual absorption plants do not incur such drastically reduced earnings as do the tail gas recovery plants, but the rate of return is still reduced to an unattractive level, so new plants of this size would not be considered.

In contrast, the 1,500-ton-per-day model plant demonstrates that large acid plants enjoy attractive rates of returns at relatively low contract prices for acid. Unit control costs are much lower for these high volume plants. Consequently, earnings and rates of return are less severely affected by the imposition of air pollution control costs. Those plants controlled by tail gas recovery systems realize a reasonable rate of return. Large new dual absorption plants realize an even higher rate of return.

Large acid plants could operate profitably unless market over-supply conditions become worse,forcing further trimming of profit margins. The high probability of this makes investment in contact acid plants risky.

b. Impact on Firms

Virtually all sulfuric acid production is by large diversified corporations or captive intermediate processes of manufacturing firms. Such firms will experience little difficulty in acquiring the necessary investment capital to undertake the control investment if they find it economical to do so. Control costs represent such a small portion of the total costs incurred by these firms that they will cause little impact on corporate profits.

Also, in any case where it is economical to construct a new plant, the additional investment required for control equipment would have little influence on the firm's ability to raise capital. Although the control investment increases the total investment by 20 to 50 percent, virtually all sulfuric acid plants are owned by large diversified corporations which would have little difficulty in acquiring the additional capital.

c. Demand Elasticity and Cost Shifting

The demand for sulfuric acid is derived from the demand for the products in which it is used; thus its demand is relatively inelastic in the short run. Since sulfuric acid is combined, in almost fixed proportions, to other inputs, small price changes have little effect on its consumption. Even moderate changes in sulfuric acid prices are unlikely to induce short-term adjustments in the amount used because shifting to an alternative input would involve changes in plants, processes, products, and expenditures that would generally exceed any savings likely to result from substitution.

In the long run, the demand for sulfuric acid is probably more elastic, at least to sizable changes in price. Substantial increases in price might outweigh the economic and technological advantages which sulfuric acid currently enjoys over substitute products. Some degree of process change and product substitution would undoubtedly result from sustained high prices.

Persistent high prices of sulfuric acid are increasingly unlikely as the number of firms recovering and producing acid expand and as competition intensifies. High prices would also induce many additional firms to enter the market since sulfur, in various forms, is widely available and capital costs are not prohibitive. As supply increased, prices would soon be driven down.

Despite relatively inelastic demand for sulfuric acid, the current oversupply and intense competitive pressures indicate that it will not be possible for most firms to pass on the full cost of pollution control, at least until a balance is attained between supply and demand. Firms serving isolated or captive markets will probably adjust price to cover control costs. However, those serving the open market will adjust price only to the extent that the most efficient firms adjust their prices. It is assumed, therefore, that for the period through FY 1977, the open market price of sulfuric acid will increase by only $0.50, or 1.5 percent, reflecting the control costs of large dual absorption plants.

d. Effect on the Industry

Many small firms--primarily those of less than 250-tons-per-day capacity--which serve the open market will be unable to generate sufficient cash flows to warrant an investment in control equipment. Only those firms which serve isolated markets at higher than average prices will find it economical to control and to continue operating their acid plants.

However, firms which produce sulfuric acid as a necessary byproduct will be forced to implement controls and to continue operating their acid plants regardless of the unprofitability of that investment. Their only recourse would be to close their entire facility, which is unlikely.

Captive sulfuric acid plants will continue to produce unless the cost of control makes it more economical to buy acid. Again, many firms with captive contact process acid plants of less than 250-tons-per-day capacity will close their plants and purchase acid on the open market. Virtually all chamber process plants will be closed because they experience considerably higher control costs than do contact process plants.

Also, many large acid plants older than 10 years will be shut down and replaced with new, larger, dual absorption plants. The limited accounting life of such an old plant would not warrant installation of gas-cleaning equipment. The additional investment required for renovation and higher operating costs of an old plant make it an unattractive alternative to a new plant.

Of far greater significance to the industry than control cost is the effect of air pollution control laws requiring control of sulfur oxide emissions into the atmosphere. Smelters have already begun to recover large quantities of sulfur oxides in the form of sulfuric acid. Technology is under development whereby electric power companies will eventually be able to produce large volumes of recovery acid for the open market. Were it not for the oversupply created by this byproduct acid, existing conventional plants could pass on the full cost of pollution control in higher prices. Instead, byproduct acid not only prevents the recovery of control costs but threatens to displace much of the conventional acid production.

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V. CONCLUSIONS

A. General Economic Impact of Air Pollution Control

The foregoing analyses indicate that control of air pollution emissions from solid waste disposal, stationary fuel combustion, and industrial processes will require an investment of approximately $10,086 billion to control the capacity estimated to be in existence in FY 1977. This estimate is based on projected industrial and population growth, which will substantially increase the sources of pollution and required investment in control equipment over that required for 1967. The total estimated annual cost of these controls, including depreciation, finance, and operating expenses, would then amount to approximately $3.885 billion per year by FY 1977. Both figures are based on 1970 prices.

These figures are large in absolute amounts; however their significance can be shown more clearly by comparing them with the related figures for the national economy. Similarly, if the gross national product (GNP) of the United States in FY 1977 is $1.3 trillion, the annual cost of $3.885 billion in that year will take approximately 0.3 percent of the Nation's gross output.

Chapter 5: Aggregate Price Impact

I. INTRODUCTION

The aggregate or macroeconomic impact of expenditures for air pollution control on the national economy includes effects on the levels of demand and supply of total production and on prices, employment, and economic growth. For example, the majority of investment expenditures for pollution control will raise costs without proportionally increasing output. Although some of the higher costs are expected to be transferred into higher consumer prices, they will also affect profits in some industries. Since the rate of investment is usually considered a function of expected profits, prospects for reduced profits due to the costs of controlling emissions may make some firms in some industries reduce their rates of investment. Such behavior by a substantial number of firms could reduce employment opportunities in the affected industries.

Further, if the demand for capital to finance investments for pollution control causes interest rates to increase, expected profits could be reduced which would also discourage investment. Reduced rates of investment would reduce economic growth. The rate of economic growth might also be depressed if the nonproductive pollution controlling investment significantly reduced the economy's overall rate of productivity.

For some products, higher prices may alter established supply and demand conditions and eventually change resource allocation. For example, if consumers choose to substitute purchases of other goods and services for those with increased prices, the reduced demand for the products of several industries will shift employment and income distributions. Higher prices may also decrease the amount of exports and the rate of investment and require a higher level of Government revenues to finance the same level of Government expenditures. However, even a comprehensive study of production, prices, employment, and economic growth would not be complete since it would include only the benefits to the industries fabricating control equipment, not the social benefits derived from cleaner air.

Such a comprehensive analysis would be a complex task. The necessary economic methodology is available but is beyond the more limited scope of this study.

This analysis is primarily confined to the projection of the impact of expenditures for air pollution control on prices paid by final purchasers of the Nation's output. The focus is on consumer prices. However, investment, Government expenditures, and export prices have been examined briefly and the direct impact of price increases on these sectors of the economy has been projected.

The emphasis on prices reflects the major role they play in a competitive economy where they reflect values and determine what is to be produced as well as the organization and distribution of production. For example, significant changes in the relative prices of products will alter the patterns of resource allocation. Such alterations would feed back through the economy and possibly affect the distributions and levels of production, employment, and income; the profitability of investment; the U.S. competitive position in foreign markets; and the productivity and rate of investment thereby influencing the rate of economic growth. For this reason, therefore, this analysis focuses on projecting price impacts.

The impacts projected are initial, once-and-for-all increases in the 1977 price level due to the costs of emission control for the industrial and mobile sources. The projected increases more closely resemble cost-push inflation rather than the classic demand-pull type. The consumer price index used is the Implicit Price Deflator for Personal Consumption Expenditures (PCE), which is a Paasche-type measure of consumer price changes; that is, the current composition of expenditures is used to weight and compute the index. (In this case, the 1977 distribution of personal consumption expenditures has been projected and used for weighting the price increase.) Although more reflective of the "cost of living" than the fixed weight or Laspeyres-type of index, the Implicit Price Deflator index is not a true measure of the cost of living to the extent that consumers substitute one purchase for another or to the extent that any consumer differs from the arithmetic average. Neither does it include income and property taxes and interest paid by consumers. Nevertheless, the measure is a good indicator of price movements and a fairly good surrogate for the cost of living.

On the basis of the analysis presented below, it appears that the costs of meeting emission standards for both the stationary and mobile sources will increase by less than 1 percent over the 1971-77 interval. In the aggregate it appears that there will not be significant impact on the prices of exports, the prices of investment expenditures for new plant and equipment, or on the prices of goods and services purchased by Government. This is, in part, because the projected changes in prices are quite small and would occur over several years, rather than instantaneously, as calculated here.

Although consumer response to the projected higher prices is not explicitly examined, it appears, with one exception, that there would be only a minimal shifting of consumer expenditures, since the projected price increases are fairly small. The exception is consumer expenditures for automobiles. New car prices are projected to increase significantly. As a result of the higher prices, consumers may defer purchases of a new car, extend the service life of their old vehicles, "buy down" in the product line, forego the purchase of optional equipment (e.g., air conditioners), or substitute other forms of transportation. These possibilities were not examined in this study.

The impacts of the projected price changes due to higher prices for controlling air pollution will probably not significantly affect the balance of payments, the rates of investment and economic growth, or the levels of Government expenditures and taxation. However, if the full spectrum of pollution control measures were evaluated together rather than air alone, the aggregative impacts are likely to be significantly different.

II. THE PRICE MODEL

Using input-output relationships, a price model has been developed to project the impact of the estimated initial price increases for each of the subject industries on the prices of goods and services purchased by consumers, by businesses for investment, by Federal, State, and local governments, and by foreign countries.

Input-output analysis uses a table or matrix which shows, for a specific point in time, the distribution of sales and purchases by each industry. The basic table of transactions can be mathematically transformed into a table of interindustry coefficients which represent the direct and indirect output of each industry required to deliver a dollar's worth of output of any other industry to consumers, investment, Government, or exports. Since it identifies the structure of each industry's inputs, the table can be used to estimate the impact of a price increase in any input to any industry, on each industry's price. Further, by developing the structure of consumer, investment, Government, and export purchases on an industry-by-industry basis, the impact of industry price increases on the prices paid by those final demand categories can also be estimated.

The U.S. Department of Commerce input-output table of the 1963 economy was used to project price impacts. The basic table has 364 industries and 4 components of final demand. However, consumer demand sector of final demand was extensively augmented--it now contains 12 categories and 80 subcategories of personal consumption expenditures. Coefficients necessary to expand the consumption sector were developed from data provided by the Office of Business Economics. The entire model was subsequently programmed for computer manipulations.

Since the input-output table is for 1963 and does not represent the 1977 structure of production, the projected price changes are approximate only, even given the validity of the assumptions stated above. Between 1963 and 1977 changes in prices, technology, and product mix will alter the interindustry coefficients. Although some of these changes can be projected, such an effort is beyond the current scope of this study. Nevertheless, the results of this analysis do provide a useful first approximation of the projected price changes.

Because this analysis of prices represents a substantial increase in the depth of analysis over that presented in the 1970 report, direct comparisons are difficult. For example, the computer solution has permitted examinations of the price relationships of 364 industries rather than last year's 72; further, this year's analysis has focused on final demand prices, whereas last year's emphasized industry prices (especially the prices in two major industries, construction and motor vehicles). Also, the initial price increases projected for the industries have been updated, on the basis of new data and analysis. This analysis is, therefore, not comparable to that presented in the 1970 Congressional Report.

III. PROJECTED PRICE INCREASES

A. General

Gross national product (GNP) is the final value of all goods and services produced in 1 year. It was assumed that the price increases projected for the industries will be passed along to the four components of GNP: consumer expenditures, business expenditures for investment, Governmental expenditures, and purchases of U.S. products by foreigners. The extent to which the prices of any component will increase is dependent on the size of the price increases in the industries and the components' industrial structure. Table 5-1 shows the 1977 price increases projected for the stationary and mobile sources if all control costs were passed on. However, the actual price increases that will occur will depend on the supply and demand conditions, both within each industry and in other industries competing for major markets. These supply-demand analyses are discussed in Chapter 4.

Figure 5-1 shows the 1970 distribution of GNP and indicates the relative importance of each of the 4 final demand components in the economy. Personal consumption expenditures (63%) are the largest and would be even higher if residential construction were included as a consumer purchase rather than as an investment expenditure. Government expenditures (23%) have been the second largest since 1952 when they surpassed investment expenditures. Investment (14%) and net exports of goods and services (0.4%) are the smallest and most volatile components.

B. Impact on Consumer Prices

Personal consumption expenditures (PCE) consist of consumer purchases of durable and nondurable commodities and services and comprise two-thirds of GNP (Figure 5-1). The distribution of PCE has been shifting and is expected to continue to shift due to economic and demographic changes as well as changes in consumer tastes. To weight the price increases for 1977, it was necessary to project the 1977 distribution of PCE.

If the full price increases projected in Table 5-1 occur, then consumer prices in 1977 are projected to increase about 0.7 percent. Well over half of the increase is due to the projected 10 percent higher prices for passenger cars; the remainder is primarily due to higher prices for electricity.

TABLE 5-1. PROJECTED 1977 PRICE INCREASES IN STATIONARY AND MOBILE SOURCES

Sources		Projected Price Increases (percent)
Mobile Sources		
New Automobiles		10.0
New Trucks		4.0
Solid Waste Disposal		1/
Stationary Fuel Combustion		
Small & Intermediate Boilers		1/
Steam Electric		4.3
Industrial Processes		
Asphalt Batching		3.0
Cement		2.2
Coal Cleaning		1.5
Grain Plants:	Handling	1.3
	Milling	0.1
Gray Iron Foundries		2.6
Iron and Steel		1.2
Kraft (Sulfate) Paper		0.7
Lime		1.8
Nitric Acid		0.0
Petroleum Products & Storage		0.0
Petroleum Refineries		0.0
Phosphate Fertilizer		0.5
Primary Nonferrous:	Copper	5.7
	Lead	8.2
	Zinc	7.1
	Aluminum	7.0
Secondary Nonferrous:	Aluminum	1.2
	Copper	0.1
	Lead	0.1
	Zinc	0.2
Sulfuric Acid		2.4

1/ Projected price increases are not estimated due to lack of sufficient data.

Only a few of the stationary sources (steam-electric power plants, iron and steel, aluminum reduction, and iron foundries) are large enough, and are projected to have high enough price increases to signficantly influence consumer prices.

As Table 5-2 shows, the largest increase in consumer prices is

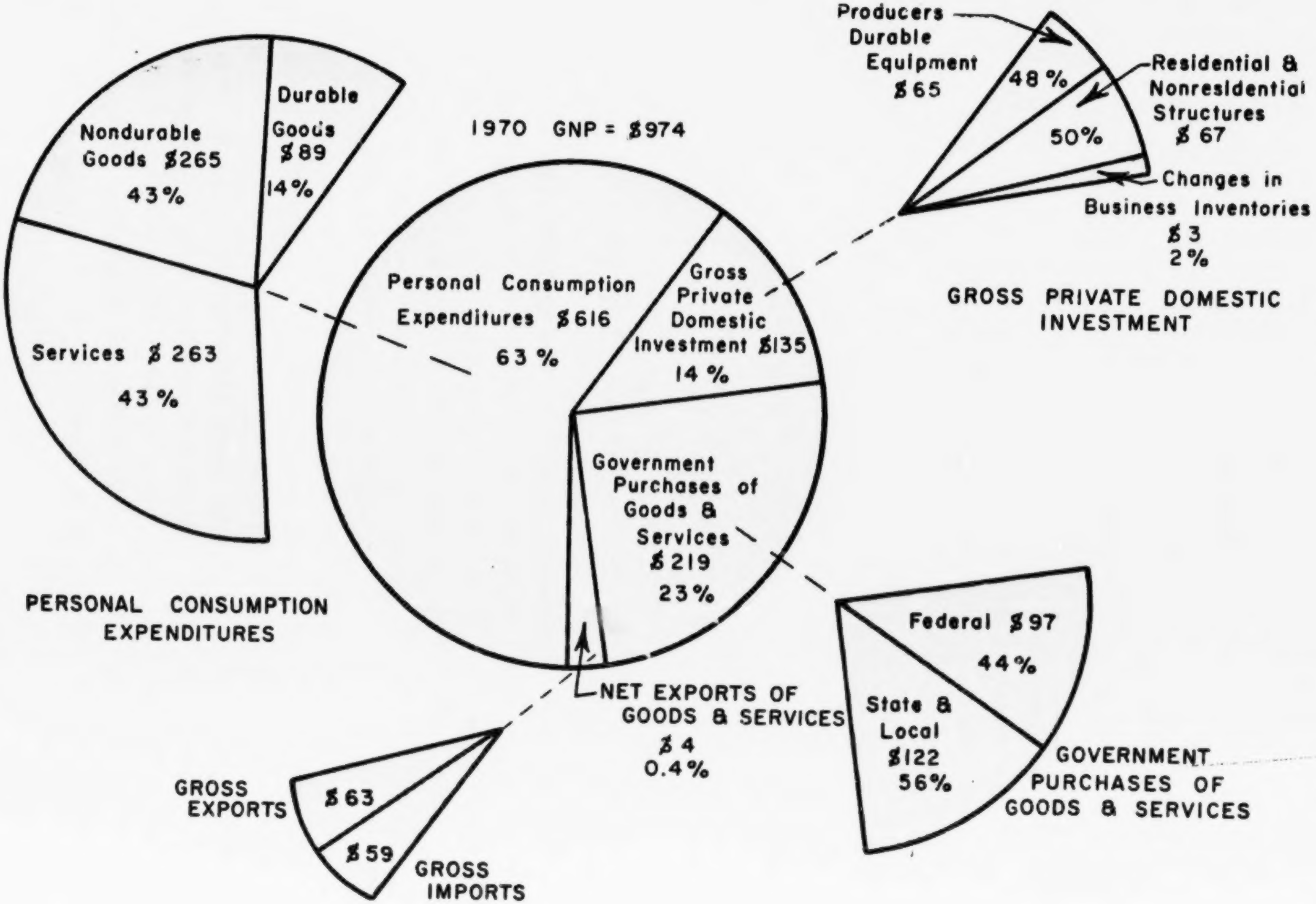

Fig. 5-1. Distribution of 1970 Gross National Product in Billions of Current Dollars.

Source: U. S. Department of Commerce, Survey of Current Business

TABLE 5-2. PROJECTED INCREASES IN CONSUMER PRICES, 1977

	Personal Consumer Expenditure Category	Price Increase (percent)
I.	Food and Tobacco	0.1
II.	Clothing, Accessories, and Jewelry	0.1
III.	Personal Care	0.1
IV.	Housing	0.0
V.	Household Operation	0.5
VI.	Medical Care Expenses	0.1
VII.	Personal Business	0.1
VIII.	Transportation	4.3
IX.	Recreation	0.1
X.	Private Education and Research	0.2
XI.	Religious and Welfare Activities	0.2
XII.	Foreign Travel and Other, Net	0.2
	Personal Consumption Expenditures[1/]	0.7

[1/] weighted total

projected for transportation, which is expected to comprise 14 percent of PCE in 1977, or about the same as its current share. The 4.3 percent projected increase in transportation prices is primarily due to the increase in motor vehicle prices, but to some extent also due to higher electricity, iron and steel, iron foundries, and aluminum prices.

The projected price increases for six of the twelve PCE categories are expected to be about 0.1 percent primarily due to higher electricity and motor vehicle prices. For clothing, accessories, and jewelry, higher prices for shoes, clothing, cleaning, jewelry, and watches all contribute to the increase. For food and tobacco the increase is primarily due to higher prices for food purchased for off-premise consumption and purchased meals and beverages. For personal care, higher prices for toilet articles are the main reason for the increase. For medical care, prices are expected to increase due to higher hospital and sanitarium rates. For personal business, higher prices for brokerage and banking services, life insurance, legal, and funeral and burial expenses all contribute to the projected increase. Recreational prices, the sixth category with a 0.1 percent price increase, will have higher prices due to higher radio and television receiver, records, and musical instruments prices.

Three small PCE categories are expected to have price increases of about 0.2 percent primarily due to higher electricity prices. These are private education and research, religious and welfare activities, and foreign travel and other, net.

Household operation prices are projected to increase 0.5 percent due to higher electricity prices. Housing prices, however, which are primarily actual or inputed rents, are not projected to increase. The prices of new houses (residential construction) are expected to increase (0.2%), but they are included in investment in accordance with the conventions used in national income accounting.

To determine whether or not there would be a differential effect of the price increases on families in different income classes, the distribution of family expenditures by income class was examined. Since the percentage of income spent on food and tobacco, personal care, housing, household operation, and medical care expenses generally declines with increases in family income, price increases in these categories would weigh most heavily on families in the lower income brackets. On the other hand, the percentage of income spent on clothing, personal business, recreation, education, and religious and welfare activities increases with increases in family income, so price increases in these categories would weigh most heavily on consumers in the higher income groups.

Expenditures for transportation are largest for the middle income groups on a percentage basis; the lower 24 percent of families and the upper 2 percent of these groups spend about three-fifths and four-fifths respectively of the middle income group's percentage of transportation expenditures. Because transportation costs are projected to increase the most (4.3%) and because they are a significant share of all income groups' PCE, the differential impacts of the price increases by income groups tend to be dominated by the distribution of transportation expenditures. For this reason, the middle and upper income groups would probably be affected to a greater extent on a percentage basis than those families in the lower and the very highest income groups.

C. Impact on the Other Components of Final Demand

Gross private domestic investment, Government purchases of goods and services, and net exports of goods and services comprise the remaining one-third of GNP. Since the price increases by the industries will also be passed along to these three components (as well as to PCE), some tentative conclusions have been drawn regarding the impact of the industry price increases on these other components of final demand. The structure of investment, Government expenditures, and foreign trade presented in the 1963 input-output table has been used for these analyses.

1. Impact on the Prices of Gross Private Domestic Investment

Gross investment includes expenditures for residential and nonresidential structures and for producers' durable equipment. (Net change in business inventories, also a part of investment, is not included in this price analysis.) These expenditures are a volatile component of GNP--their level and distribution shift in response to anticipated business profits. Since many of these expenditures are for residential structures or for equipment to make consumer goods, most of the changes in investment prices will probably be passed on to consumers.

This analysis projects the price increases in the major investment producing industries and identifies the major industries purchasing each major investment product. As with consumption, higher investment prices may discourage some marginal investment projects, postpone others and may encourage substitution of some investment goods for others. These possibilities are not investigated. However, the magnitude of the projected price changes offers a basis for drawing some inferences regarding the changes in the demand for investment goods. The changes in resource allocation are not likely to be significant as the result of higher prices for investment goods since the projected price increases are about 0.5 percent for all investment goods.

New construction is the largest investment producing industry with over half of total sales for investment. Construction prices are projected to increase by 0.2 to 0.4 percent, depending on the specific construction industry, primarily as results of higher copper, electric, iron and steel, iron foundries, and motor vehicle prices. Every industry in the economy, including consumers who purchase houses, is a purchaser of new construction and would be affected to some extent by higher construction prices.

Motor vehicles and equipment is the next largest investment producing sector, and like construction, motor vehicles are purchased by virtually every sector in the economy. Projected higher prices for automobiles (about 10.4%) and for trucks (about 4.4%) are primarily due to the costs of emission control devices which will be installed. The major motor vehicle purchasing industry is transportation and warehousing. Major affected industries within the transportation industries include trucking, busline operations, and taxi cabs.

The machinery industries are frequently cited as key elements in investment activities since they frequently embody technological innovations. These industries together are responsible for 15 percent of investment expenditures. All major industries in the economy purchase machinery products. The price increases projected for the machinery industries are about 0.4 to 0.7 percent, depending on the specific type of machinery. Higher electricity, truck, iron and steel, iron foundries, copper, lead, zinc, and aluminum prices are the primary reasons for the higher prices.

The implications of the effects on investment are compounded by uncertainties regarding the availability of investment funds and the impact on capital markets of additional spending for air pollution control. For example, this study has projected the investment requirements of 17 industrial sectors, for the steam-electric generating industry, and for public and private solid waste disposal through FY 1977--the projected total public investment is approximately $300 million, and the total investment for private enterprises is estimated at $9,076 million (steam-electric $3,960 million; other industries $5,416 million). Some analysts have questioned the capability of the capital market to absorb demands of this magnitude and the willingness of investors to provide funds in these amounts for investments that do not, of themselves, increase the productive capacity of business. However, it should not be assumed that the entire $9,076 million will be invested in 1 year; this is the total required to provide the controls described for plants in existence in 1967 plus those built through FY 1977, so part of the total has already been invested. Such industries as paper, steel, nonferrous metals, cement, petroleum, and iron foundries have already made substantial expenditures on pollution control, and the portion that remains will probably be financed over at least 3 years, and not more than half, at most, of the total will be raised in 1 year, say, not more than $4 billion. A substantial share of the funds will come from internal financing (out of retained earnings) although it is difficult to estimate how much this may be. Of the remainder, perhaps as much as 80 percent may come from increased debt and 20 percent from equity funds. Thus, probably no more than $2.5 billion may be drawn from the bond market in any 1 year. We feel that the market should be able to absorb demand of this magnitude, especially if (as indicated in the analysis of some industries in Chapter 4) other investment demands may be postponed.

Assuming that municipal voters will approve the required bond issues, the reaction of the financial markets to new bond offerings will probably be the same as for any other municipal borrowings because the amounts projected are not large relative to other public debt issues.

If control costs are passed on to consumers in the form of higher prices in many of the industries requiring the greatest investments, investors should be able to obtain funds, so long as revenues, in those instances, increase by enough to service the debt or to maintain dividend rates. The greatest difficulties will be experienced by small, financially weak firms with limited capabilities for raising funds. Those dependent on a limited line of bank credit, in particular, may find it virtually impossible to raise even modest amounts for investments that contribute nothing to earnings.

2. Impact on the Prices of Government Expenditures

Purchases of goods and services by Federal, State, and local governments have been the second largest component of GNP since 1952. Prior to 1952 the relative positions of Government and investment alternated several times reflecting the level of business and military activity.

The impact on prices paid by the Federal Government for goods and services is projected to be about 0.1 percent. Defense expenditures would be more affected than other prices due to higher prices for military hardware. The increase is small because a large share of expenditures is for employee compensation which will not be affected and because of the lack of a substantial increase in the price for any major industry producing goods or services which are Federal Government budget items.

a. Federal Government

Federal Government expenditures for goods and services include compensation of employees (46% of total 1970 expenditures), structures (3%), and other purchases (51%). Higher industry prices will be reflected in higher prices paid by Government for structures and other purchases. The composition of two categories of Federal Government purchases--defense and other--were examined. Defense accounted for 78 percent of 1970 Federal Government purchases of goods and services. The projected price increase in the major defense purchases are 0.1 to 0.3 percent excluding motor vehicles. (Although new automobile prices are projected to increase about 10%, defense spending for all motor vehicles is only about 1%, of defense expenditures.) The industry with the largest share of defense purchases (3%) is radio and TV communications equipment; its prices are projected to increase about 0.17 percent.

Other programs make up the remaining 22 percent of Federal Government expenditures. Major functions include space research and technology; general government; international affairs and finance; education; health, labor, and welfare; veterans benefits and services; commerce, transportation, and housing; agriculture and agricultural resources; and natural resources. Price increases here are expected to be small. The largest increase is projected in aircraft and aircraft equipment prices due to higher aluminum and electricity prices.

b. State and Local Government

State and local government purchases resumed the pre-World War II position of being larger than Federal Government purchases in 1965[1] and are expected to continue to be for the foreseeable future. Major nonemployee compensation expenditures by State and local governments are currently for education (44%); health, welfare, and sanitation (16%); safety (8%); and others including general government, transportation, agriculture and natural resources (32%). Compensation of employees represents over half of current State and local government purchases of goods and services. The remaining share is about equally divided between structures and other purchases.

The cumulative effect of the industry price increases projected on the prices of State and local government's expenditures is expected to be minimal. This is due to the fact that compensation of employees, the largest budget item, would be unaffected and that the price increases in the major affected industry, construction, is projected to be less than 0.5 percent.

The largest nonemployee compensation component of educational expenditures is for new buildings construction, which is projected to increase about 0.3 percent. Higher electricity and iron and steel prices are the primary causes of the increase. Most other categories are projected to increase about 0.1 or 0.2 percent.

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[1] Measured in current dollars.

State and local government expenditures for health, welfare, and sanitation are primarily for construction; meat, chemicals, drugs, electric power, miscellaneous business services; hospitals; and other medical and health services. Price increases of about 0.1 to 0.4 percent are projected for all but electricity, where an increase of about 4.3 percent is projected.

State and local government expenditures for safety are for police, fire, and correction services. These primarily include new construction, petroleum and related products, motor vehicles and parts, and miscellaneous business services.

Motor vehicles and parts expenditures show the largest projected price increases. Since they comprise 2.5 percent of State safety expenditures, they will have the most significant impact on the price on safety related expenditures.

The remaining component of State and local government expenditures is for other goods and services. The largest expenditures are for maintenance and repair construction.

3. Impact on the Prices of U.S. Foreign Trade Items

Foreign trade, currently the smallest component of GNP, contributes less than 1 percent of total U.S. output. Net exports have generally been declining since 1964 due to the inability of the growth in exports to match the growth in imports. There are many sources of the decline in the U.S. trade surplus; however, an element frequently cited is the inflationary pressures which have priced some U.S. goods out of world markets. It is interesting to note that export prices have risen 13 percent in the last 6 years after remaining virtually constant from 1951 to 1964. Prices of imports have risen also since 1964, but by only two-thirds of the increase in export prices. Our trade position will be further aggravated to the extent that air pollution control expenditures by industry cause increases in the prices of U.S. exports and in the domestic substitutes for imports.

The extent to which the U.S. trade position is affected by air pollution control will depend on changes in the relative prices of U.S. and foreign goods competing for world markets. Since most industrialized countries have some type of air pollution control program, any estimate of the increase in the prices of U.S. exports probably overstates the situation and is not reflective of the change in relative prices. We do not here consider the possible impact of rising U.S. prices due to pollution control on import demand. To the extent that rising domestic prices increase import demand, the balance of trade position will deteriorate.

Major U.S. exports are agricultural products, food and kindred products, chemicals and selected chemical products, and motor vehicles and equipment.

In 1968, agricultural products including foods, feeds, and grains comprised over 18 percent of U.S. exports. Most agricultural products are sold to the developed countries[2/] especially the Common Market countries, Canada, and Japan. The highest price increase projected for agricultural products is 0.07 percent for cotton primarily due to higher electricity prices. Western European countries and Japan purchase almost all U.S. cotton exports.

Chemicals and chemical products were about 8 percent of 1968 U.S. exports. Chemicals and chemical products are primarily sold to the Common Market countries, Canada, and the Latin American countries. The major chemical products which are exported include industrial inorganic and organic chemicals, agricultural chemicals, and miscellaneous chemical products. The prices of industrial inorganic and organic chemicals are projected to increase by 0.3 percent, primarily due to the impact of higher iron and steel prices.

[2/] Western Europe, Canada, Japan, Australia, New Zealand, and Republic of South Africa.

Motor vehicles and equipment exports consist of new and used passenger cars, trucks, buses, special vehicles, and parts, bodies, and accessories. Together, they comprised 10 percent of U.S. exports in 1968. Canada and the Latin American countries are the largest purchasers of U.S. exports of motor vehicles--together purchasing 80 percent of total exports of this category. To the extent that Canada and the Latin American countries require motor vehicles to meet the same or similar emission standards as assumed for the U.S. in 1977, prices of exported automobiles would increase about 10 percent and trucks about 4 percent. If emission control devices are not installed on motor vehicles for export and the only price increases projected are due to higher input prices, the projected impact on motor vehicle production prices would be about 0.4 percent.

Appendix I

Assumed Emission Standards

I. INTRODUCTION

Under the Clean Air Act, as amended in 1970, air quality standards have been established for the whole country. Each State is required to adopt and to submit implementation plans to the Administrator of the Environmental Protection Agency for the emission reduction strategy and enforcement thereof to achieve national standards for particulates, sulfur oxides, nitrogen oxides, hydrocarbons, and carbon monoxide.

For this report, uniform emission standards were selected without going through the various steps of emission inventories and diffusion calculations to determine acceptable emission standards for achieving air quality standards in each air quality control region. The basis for the selections was the sample limitation procedures promulgated in the Federal Register, Volume 36, Number 158, Part II, "Requirements for Preparation, Adoption, and Submittal of Implementation Plans", August 14, 1971.

Newly constructed and modified sources are subject to national standards of performance based on adequately demonstrated control technology in accordance with Section 111 of the Clean Air Act, as amended. In this report, steam-electric power plants, nitric and sulfuric acid plants, cement plants, and municipal incinerators scheduled for construction after January 1, 1972, were assumed to be subject to national standards of performance promulgated in the Federal Register, Volume 36, Number 159, "National Standards of Performance for Stationary Sources", August 17, 1971.

II. STATIONARY SOURCES

A. Standards for Particulates

For industrial processes, the process weight rate regulations (Table I-1) are the bases of control cost estimates. These regulations limit the weight of particulate emissions per hour as a function of the total weight of raw materials introduced into a process operation. For sulfuric acid plants, the allowable mist emission is 0.5 pounds per ton of acid produced; for incinerators, the particulates are limited to 0.10 pounds per 100 pounds of refuse charged; for fuel-burning equipment, the particulates are limited to 0.10 pounds per million Btu of heat input. Limitations for incinerators and for fuel-burning equipment are based on the source test method for stationary sources of particulate emissions published by EPA in 40 CFR-Part 60, December 22, 1971, Federal Register.

B. Standards for Sulfur Oxides

For fuel-burning equipment, cost estimates are based on mass emission rate of 1.50 pounds of sulfur dioxide per million Btu input. This limit is approximately equivalent to a sulfur content of 1.0 percent by weight in coal and 1.4 percent by weight in oil. For sulfuric acid plants, a mass rate of 6.5 pounds of sulfur dioxide per ton of acid is used for existing sources. Primary copper, lead, and zinc smelters are assumed to limit sulfur oxide emissions to 10 percent of sulfur (measured as sulfur dioxide) in the ore. Sulfur recovery plants at refineries are limited to 0.01 pounds of sulfur emissions per pound of input sulfur.

C. Standards for Carbon Monoxide

Cost estimates were based on treatment of all exhaust gases to reduce the weight of carbon monoxide emissions by at least 95 percent.

D. Standards for Hydrocarbons

For industrial processes, cost estimates were based on treatment of all exhaust gases to remove organic material by 90 percent (or more) by weight. For petroleum products storage, it was assumed that all stationary tanks, reservoirs, and containers with more than a 40,000-gallon capacity and with a vapor pressure of 1.5 pounds per square inch absolute (or greater) must be equipped with floating roofs, vapor recovery systems, or other equally efficient devices. In addition, it was assumed that submerged filling inlets must be installed on all gasoline storage tanks with a capacity of 250 gallons or more.

E. Standards for Nitrogen Oxides

No specific cost estimates were made pertinent to the reduction of nitrogen oxides. Limestone injection scrubbing, assumed for power plants, can reduce some oxides of nitrogen by 20 percent. Existing nitric acid plants are restricted to 5.5 pounds of nitrogen oxide per ton of acid produced.

III. MOBILE SOURCES

Table I-2 summarizes the current and projected emission control requirements for reducing hydrocarbons, carbon monoxide, and nitrogen oxides emissions from passenger cars and light-duty trucks through Fy 1977. This table is based on information available through August 15, 1971. Table I-3 is the forecast of emission control requirements for reducing the same pollutants for heavy-duty trucks through Fy 1977. The assumed standards no longer include particulates. This change was brought about by the assumption that unleaded or low lead gasoline will be in widespread use during the next 5 years; removal of lead reduces particulates from gasoline engines by 75 to 80 percent (by weight).

Table I-4 provides the reports and estimates of motor vehicle production that served as a basis for cost estimates.

TABLE I-1. ALLOWABLE RATE OF PARTICULATE EMISSIONS BASED ON PROCESS WEIGHT RATE [1]

Process Weight Rate (lbs/hr)	Emission Rate (lbs/hr)
50	0.30
100	0.55
500	1.53
1,000	2.25
5,000	6.34
10,000	9.73
20,000	14.99
60,000	29.60
80,000	31.19
120,000	33.28
160,000	34.85
200,000	36.11
400,000	40.35
1,000,000	46.72

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[1] To interpolate the data for the process weight rates up to 60,000 lbs/hr, use the equation

$$E = 3.59 p^{0.62} \qquad p \leq 30 \text{ tons/hr} ;$$

to interpolate and extrapolate in excess of 60,000 lbs/hr, use the equation

$$E = 17.31 p^{0.16} \qquad p > 30 \text{ tons/hr} ;$$

where E is emissions in pounds per hour, and p is process weight rate in tons per hour.

TABLE I-2. CURRENT AND PROJECTED EMISSION CONTROL REQUIREMENTS FOR AUTOMOBILES AND LIGHT TRUCKS (6000 LB. GVW OR LESS)

Model Year	Test Procedure[1]	Exhaust Emissions, Gm/Mi			Evaporation Grams/Test	Assembly Line Test
		HC	CO	NOx		
1968[2]	FTP	(275 ppm)	(1.5 vol.%)	NR	NR	NR
1969[2]	FTP	(275 ppm)	(1.5 vol.%)	NR	NR	NR
1970	FTP	2.2	23	NR	NR	NR
1971	FTP	2.2	23	NR	6	NR
1972	CVS	3.4[3]	39[3]	NR	2	NR
1973	CVS	3.4	39	3.0	2	4/
1974	CVS	3.4	39	3.0	2	4/
1975[5]	CVS	0.41	3.4	3.1	2	4/
1976[5]	CVS	0.41	3.4	0.4	2	4/
1977[5]	CVS	0.41	3.4	0.4	2	4/

Notes:

NR - No Requirement

GVW - Gross Vehicle Weight

1/ - Federal Test Procedure (FTP), 7-mode cycle.

- Constant Volume Sampler (CVS) using 1372-second driving cycle.

2/ - Standards for 1968 and 1969 are expressed as parts per million (ppm) or volume percent.

3/ - The larger numbers for HC and CO standards beginning 1972 are due to the fact that the CVS procedure gives larger readings than FTP. On an equal test procedure, 1972 standards are more stringent than 1971 and do not represent a relaxation of previous requirements.

4/ - Assumes Federal requirement for test on 3 percent of nationwide sales expected starting 1973, using a new short test cycle now under development.

5/ - Definition of standards was published by EPA on 7-2-71. A hot start cycle is added to the procedure beginning in model year 1975.

TABLE I-3. CURRENT AND POSSIBLE[1/] EMISSION CONTROL REQUIREMENTS HEAVY-DUTY VEHICLES (OVER 6000 LB. GVW)

GASOLINE ENGINES

Model Year	Test Procedure[2/]	Exhaust Emissions 3/				Evaporation Grams/Test
		Concentration-ppm or %		Mass-gm/ghp hr		
		HC	CO	HC+NOx	CO	
		ppm	Vol. %			
1967-69	NR	NR	NR			NR
1970-71	Eng. Dyn.	275	1.5			NR
1972	Eng. Dyn.	275	1.5			NR
1973-74	Eng. Dyn.	275	1.5			10[4/]
1975-77	Eng. Dyn.			5	25	10

DIESEL ENGINES

Model Year	Test Procedure[5/]	Exhaust Emissions Mass-gm/bhp hr		Smoke %Obscure[6/]
		HC+NOx	CO	
1967-69	-	NR	NR	NR
1970-74	-	NR	NR	20-40
1975-77	Eng. Dyn.	5	25	20-40

NOTES:

NR - No Requirement

GVW - Gross Vehicle Weight

1/ - EPA announced on February 11, 1972, that the 1973 heavy-duty vehicle standards proposed on October 5, 1971, were being withdrawn and that new standards would be imposed for the 1974 model year instead. There was insufficient time to change this report to reflect either this new effective date or likely changes in the technical nature of the control requirements assumed in the table.

2/ - HEW engine dynamometer test cycle (steady 2000 rpm, various loads).

3/ - Concentrations are expressed on a volume portion basis through 1974, parts per million (ppm) or volume percent. After 1974 a mass basis of grams per brake horsepower-hour is used.

4/ - Evaporative control requirements may possibly be delayed until model year 1975.

5/ - EMA engine dynamometer test cycle (various stabilized speeds and loads).

6/ - HEW engine dynamometer test -- acceleration and lugging modes.

TABLE I-4. MOTOR VEHICLE PRODUCTION
(Domestic Production Plus Net Imports)

Calendar Year 1/	Numbers of Vehicles (Millions)			
	Autos	L.D. Trucks	H.D. Trucks & Buses	Total
1967	8.1	1.0	0.6	9.7
1968	10.0	1.1	0.8	11.9
1969	9.7	1.1	0.8	11.6
1970	10.0	1.2	0.8	12.0
1971	10.0	1.2	0.8	12.0
1972	10.1	1.2	0.9	12.2
1973	10.2	1.3	0.9	12.4
1974	10.4	1.4	0.9	12.7
1975	10.7	1.4	0.9	13.0
1976	10.9	1.4	0.9	13.2
1977	11.2	1.4	0.9	13.5

1/Reported numbers through 1968, estimated thereafter. Source: U.S. Department of Transportation, Federal Highway Administration, Bureau of Public Roads, with light-duty truck numbers estimated from total truck and bus numbers.

Appendix II

State Inspection Programs and
Retrofit Devices

I. INTRODUCTION

Section 107 of the 1970 Clean Air Act Amendments requires that States, in which air quality control regions have been designated, develop air quality standards and subsequently prepare implementation plans for achieving air quality meeting those standards. Since motor vehicles contribute major fractions of the emissions of carbon monoxide, nitrogen oxides, and hydrocarbons, plans for effective control of these pollutants must include controls for motor vehicle emissions.

The Federal Government has preempted the right to set emission standards for new motor vehicles prior to initial sale. After transfer of ownership, a State has the right to require that pollution emission restrictions are met by the vehicles registered in that State. Under Section 210 of the 1970 Clean Air Act Amendments, financial assistance in the form of Federal grants is available for planning, establishing, and maintaining vehicle emission inspection programs.

Several levels of vehicle emission inspection are considered as they relate to existing types of safety inspection programs. Also, because the use of retrofit devices for older vehicles has been a measure frequently proposed for emission reduction, data have been developed for this strategy.

II. EXISTING STATE MOTOR VEHICLE SAFETY INSPECTION PROGRAMS

The current State motor vehicle safety inspection programs were developed in response to the conclusion that automobiles in various stages of disrepair contribute significantly to the death toll and the injury rate of the American driving public. The acceptance of a program providing for safer automobiles through the administration of an inspection program designed to detect unsafe operating components has been slow and varied across the States. Present inspection requirements are not uniform throughout the States. Several States have very rigidly enforced safety standards, others have programs that require annual inspection of different components, and still others do not have formal safety inspection programs.

One major consideration in planning for air pollution control is the feasibility of incorporating, within existing and planned State motor vehicle inspection programs, an inspection to determine the level of emission of pollutants from automobiles and light-duty trucks. An essential step is the review of present State motor vehicle inspection programs. This section briefly outlines the characteristics of existing State motor vehicle safety inspection programs, particularly those characteristics that relate to the issue of involving emission control measures along with the present inspection [Refs. 1 and 2].

A. Current Inspection Programs

Inspection programs are generally described in terms of the regularity with which the inspections are required and the type of vehicles included. Classifications include periodic motor vehicle inspection, random spot inspection, inspection limited to certain vehicle classes, and no State-required inspection.

Currently, 32 jurisdictions (31 States and the District of Columbia) have laws which require periodic motor vehicle inspection of all motor vehicles. Only three States (Delaware, District of Columbia, and New Jersey) have State-owned inspection systems representing approximately 3.9 percent of the national motor vehicle total. The other 29 States have State-appointed systems (private service stations) representing approximately 50.9 percent of the national motor vehicle total.

In each of these States, a motor vehicle must pass a safety inspection to be permitted to operate on the highways.

Seven States have some form of random spot inspection and account for about 28.0 percent of the national total. These inspections usually involve stopping and checking vehicles on a public highway in a temporary inspection lane.

The quality of the inspection required under these random spot programs may very well be superior to some of the periodic inspection programs. However, the overwhelming advantages lie with periodic inspection in that all vehicles are inspected. Under a random spot inspection not only is the number of vehicles inspected much smaller, but the probability that a vehicle owner will take measures to correct minor deficiencies so that his car will pass an inspection that may or may not occur are undoubtedly much smaller.

Three States (Illinois, Maryland, and Arizona) have limited inspection laws at the present time and account for about 7.6 percent of the national total. Illinois only requires commercial vehicles be inspected, Maryland requires used cars to be inspected before sale, and Arizona only requires school buses to be inspected. Essentially, these States do not have inspection requirements that can be expected to exert much influence upon safe driving conditions of motor vehicles nor can it be expected that emission control measures are likely to be incorporated voluntarily along with this limited safety inspection. .

The 9 remaining States, which account for approximately 9.6 percent of the national total, do not have any State law which requires motor vehicle inspection. Therefore, it is doubtful that emission control inspection will be undertaken in these States on a voluntary basis.

B. Administration of Inspection Programs

The department or commission responsible for providing safety inspections within the States includes a wide assortment of agencies. However, the departments of Motor Vehicles, State Police, and Public Safety account for 38 of the programs or have authority to initiate programs. These departments will probably be the departments through which the control of emissions must ultimately be coordinated. However, it is possible that other agencies in the States may take the initiative in the emission control part of an inspection. In New Jersey, for example, the Department of Health has been the agency responsible for much of the developmental work in vehicle emission control and that State is moving forward in developing a statewide emissions control program.

C. Operation of Periodic Motor Vehicle Inspection Program

There are two general organizational methods of operating an inspection program. The State can establish State-operated inspection stations or it can license private stations to conduct the inspections.

1. State-Operated Stations

Currently the three States or jurisdictions that have State-operated stations (New Jersey, Delaware, and Washington, D. C.)

have facilities owned by the State, are staffed by State employees, and usually are involved only with the task of providing the inspection function. Characteristics of operation of these stations include: (1) relatively small number of stations, (2) large volume of total vehicles inspected for each station, (3) standardization of quality of inspection, and (4) limited to inspection only. Items (1) and (2) essentially are two statements of the same fact, yet each is important in discussing the feasibility of including within existing inspection programs the emissions inspection that under given alternatives could involve large outlays for capital equipment. Standardization of quality of inspection may also become more critical when the remedial steps required may include a major engine tune-up.

Many rejections for safety are overcome by a minor correction, such as adjusting a headlight or replacing a bulb that has burned out; but in the inspection programs that are State operated, the inspector cannot also serve as a mechanic. Thus a minor deficiency that can be corrected in two minutes may require the vehicle owner to spend considerably more total time in having the deficiency repaired and then waiting to go through the inspection process again.

2. State-Appointed Stations

Of the 32 States which have periodic inspection programs, 29 operate a "State-appointed system," under which the State licenses or grants to private service stations (or to owners of vehicle fleets) the authority to inspect vehicles. The specific requirements for becoming an "official inspection station" vary somewhat among States, but can be summarized as (1) having the "necessary" tools and equipment and (2) having in the employment of the establishment a person sufficiently competent to carry out the inspection.

The relevant characteristics of the inspection stations that are State-appointed are: (1) A large number of stations operate across the State. For example, North Carolina has over 4,000 inspection stations compared to New Jersey's (State-operated) 38 stations. (2) A relatively small number of vehicles are inspected per inspection station. A rough comparison being an average of 800 vehicles per station under State-appointed systems and 50,000 vehicles per station under State-operated systems [Ref. 2]. (3) Increased enforcement and standardization problems result in inspection being perhaps less thorough under State-appointed systems. (4) There is opportunity for the inspector to also serve as the repairman, especially in the on-the-spot correction of minor discrepancies. (5) A multipurpose use of the area in which the inspections are conducted. For example, the area or space in which the inspection is carried out is also used for general servicing, lubrication, and oil changes when not being used for inspection purposes.

D. Components Inspected

The equipment on the motor vehicles that is required to be inspected in safety programs differ among the various States. A review of the thirty-two States which have periodic motor vehicle inspection [Ref. 1] shows that the following items of equipment are most commonly inspected:

	Equipment Item	Number of States Inspecting
1.	Horn	32
2.	Reflectors	31
3.	Brakes	30
4.	Windshield Wipers	30
5.	Clearance Lights	29
6.	Headlights	29
7.	Steering	29
8.	Tires	29
9.	Turn Indicators	29
10.	Glass	28
11.	Tail Lights	28
12.	Exhaust System	27
13.	Stop Lights	25
14.	License Place Lights	22
15.	Side Marker Lights	22
16.	Lighting Equipment	20

--continued

	Equipment Item	Number of States Inspecting
17.	Windshield	19
18.	Wheels	17
19.	Beam Indicator Lights	16
20.	Mirrors	16
21.	Suspension	16
22.	Wheel Alignment	16

In some States there are several items of equipment or components of particular importance in controlling emission that are also inspected [Ref. 2]. These are listed below:

	Equipment Items Related to Emission Control	Number of States Inspecting	States Inspecting
1.	Crankcase Ventilation System	3	Colorado, Missouri, New York
2.	Fuel System	3	Louisiana, New Hampshire, Wyoming
3.	Fuel Tank	8	Idaho, Maine, Nebraska, New Hampshire. South Dakota, Utah, Vermont, District of Columbia
4.	Fuel Lines	1	Utah
5.	Exhaust Emission System	1	Texas
6.	Mufflers	9	Arkansas, Colorado, Indiana, Louisiana, New Hampshire, South Dakota, Virginia, West Virginia
7.	Pollution Control Devices	1	Missouri

There are a large number of other items that are inspected in one or more States. Generally, however, these are items that are inspected visually and do not require special tools, measurements, or evaluation.

E. Cost of Inspection

The fee charged for an inspection varies from a $1.00 charge in District of Columbia, Louisiana, Maine, Massachusetts, New York, New Jersey, Rhode Island, and Vermont to a high of $3.50 per inspection in West Virginia.

In the majority of these States, a small part of the total fee is passed on to the State and the remainder is retained by the inspecting station. The total revenue generated for a given State-appointed station will seldom support the full-time employment of a man just to inspect vehicles. This requires, therefore, that the majority of the men inspecting vehicles also have other duties and tasks.

F. Enforcement of Vehicle Inspection Requirements

The majority of the States with inspection programs provide for the removal of vehicles from the highways if they do not meet the inspection requirements. This is usually implemented by giving a 10- to 14-day grace period in which the motorist is required to have deficiencies corrected. When a vehicle has been inspected and has passed the inspection, a certificate in the form of a windshield sticker is normally issued.

G. Flexibility of State Programs

Many of the State statutes are stated in a manner that permits the commissioner or director of the agency charged with the responsibility for conducting the inspection to determine which items or components will be inspected.

Addition of items or equipment to be inspected could be realized in 34 of the 39 States, given that the additional items do not involve issues that may arouse the public. The authority to add additional items is clearly stated in many of the statutes but this should not be interpreted as involving only the decision of the director or commission, particularly if the additional inspection requirements (for the purpose of emission control) call for a tune-up or other major corrections in order to pass the inspection.

III. VEHICLE EMISSION INSPECTION PROGRAMS

A. Candidate Programs

Numerous test or inspection procedures exist for possible use in a State vehicle emission inspection program. These range in complexity from a simple visual inspection to a detailed measurement of emission products under certain driving conditions. The selection of the particular test procedure that is feasible, practical, and usable for a particular State depends upon many factors, and what is suitable for one State will not necessarily be suitable for another. This variation of needs from State to State can result from such factors as the vehicle density, existing inspection resources, prevailing meteorological conditions and the political "climate." Candidate inspection procedures for State vehicle emission inspection programs are listed and described in Table II-1. Each category represents

Table II-1.

CANDIDATE INSPECTION PROCEDURES FOR STATE VEHICLE EMISSION INSPECTION [REF. 2]

Visual Inspection	Determine that required control devices are present and intact; check for rough idle and unusual sounds from engine or exhaust system; check exhaust smoke density. Reject if defects observed.
Engine Tune-up Check	Check idle RPM, idle air-fuel mixture, ignition timing, and other important engine parameters. Reject if parameters out of manufacturer's specifications.
Mandatory Tune-up	Perform minor tune-up consisting of adjusting idle RPM, idle air-fuel mixture, ignition timing, and other engine parameters to manufacturer's specifications. Reject if parameters cannot be brought into specification limits.
Emission Measurement at Idle	Measure exhaust HC, CO, NO_x, opacity, and perhaps crankcase pressure of HC emissions at idle (and/or possibly at some higher RPM). Reject if emissions are above established standards.
Emission Measurement, Short Cycle	Measure exhaust HC, CO, NO_x, opacity and perhaps crankcase pressure or HC emissions while vehicle is driven through a predetermined short cycle on a dynamometer. Reject if emissions are above established standards.

a broad classification which may include, from program to program, more than one test procedure. For example, the procedures associated with the well-known Clayton key mode cycle, the New Jersey ACID cycle, and the General Motors EXIT cycle all conform to the last category: Emission Measurement, Short Cycle.

All of the designated procedures have been proposed at one time or another as appropriate for State inspection programs. Emission measurements with a long dynamometer cycle such as the Federal test were not included as candidate procedures. They were ruled out as being too expensive and complex for a State inspection procedure.

B. Program Selection

The decision to establish an emission inspection program will be based on projections of the needed reduction in aggregate emission in a particular State to maintain healthful air quality levels. Emission inspection programs may be required in some States as air quality standards and implementation plans for achieving air quality are developed as required under Sections 109 and 110 of the 1970 Clean Air Act Amendments.

Under the "worst region" concept, which is expected to be part of the Federal Guidelines for State implementation plans, the implementation plan developed for a high density urban industrialized region may be acceptable as applicable to all the air pollution control regions of the State.

Based upon the 1970 Census, there are 29 States and the District of Columbia with city populations of over 200,000 people, as listed in Table II-2. Using this criterion, the assumption is made that these cities constitute "worst regions" requiring the strategy of vehicle emission inspection and that this requirement is also applicable to other air pollution control regions within these respective States. Therefore, approximately 85 percent of the national motor vehicle total will ultimately be subjected to some form of emission inspection.

Table II-2 also gives the 1970 vehicle density per square mile and present safety inspection program although no correlation appears to exist.

Table II-2.

JURISDICTIONS WITH CITIES OVER 200,000 POPULATION, BASED ON 1970 CENSUS

	State	1970 Vehicle Density per Mi^2	Present Safety Inspection
1.	Alabama	37.1	None
2.	Arizona	9.6	Limited
3.	California	75.5	Random
4.	Colorado	13.7	Yes
5.	Florida	70.3	Yes
6.	Georgia	44.5	Yes
7.	Hawaii	61.3	Yes
8.	Illinois	94.5	Limited
9.	Kansas	19.1	None
10.	Kentucky	43.7	Yes
11.	Louisiana	37.0	Yes
12.	Maryland	178.0	Limited
13.	Massachusetts	304.0	Yes
14.	Michigan	80.5	Random
15.	Minnesota	26.2	Random
16.	Missouri	34.5	Yes
17.	New Jersey	466.0	Yes
18.	New Mexico	5.2	Yes
19.	New York	135.0	Yes
20.	North Carolina	53.7	Yes
21.	Ohio	146.0	Random
22.	Oklahoma	24.3	Yes
23.	Oregon	14.3	Random
24.	Pennsylvania	131.2	Yes
25.	Tennessee	48.0	None
26.	Texas	25.5	Yes
27.	Virginia	50.5	Yes
28.	Washington	32.9	Random
29.	Wisconsin	37.9	Random
30.	District of Columbia	3750.0	Yes

Of the thirty jurisdictions listed, two have State-owned inspection, fifteen have State-appointed inspection, three have limited inspection, seven have random spot inspection, and three have no inspection at all.

For the purpose of this analysis it will be assumed that 17 jurisdictions will incorporate emission inspection into their existing safety inspection programs and that the other thirteen states will be required to develop emission testing facilities probably in conjunction with safety inspection programs. Permanent test stations, State-owned or State-appointed, rather than mobile units will also be assumed.

No provision has been made for visual inspection because this method is considered too crude and relatively ineffective for a suitable inspection procedure. The inspection procedure is assumed to consist of some type of engine tune-up check or emission measurement, at either idle or with short dynamometer cycle, with the same rejection rate for all to determine the requirement for mandatory tune-up.

IV. RETROFIT EMISSION CONTROL DEVICES

One emission control strategy for pre-1968 model year automobiles is the use of retrofit devices. Although it is not likely that used-car owners will install these devices on a voluntary basis to any great extent, it is probable that they may be required by some States as air quality standards and implementation plans for achieving air quality are developed as required by Sections 109 and 110 of the 1970 Clean Air Act Amendments. The California Air Resources Board has established standards for pre-1968 model year automobiles of 350 ppm HC, 2 percent CO, and 800 ppm NO_x. The law provides for approval of any used-car device which meets two of the three prescribed standards without increasing the third. The law further states that a used-car device to be approved must sell for $65 or less. The California standards and criteria are serving as the primary bases for the design of retrofit emission control devices being made available to owners of older vehicles [Ref. 2].

Emission control devices or modification kits, are in various stages of development by the automotive manufacturers and independent companies [Ref. 3]. The systems developed by the auto manufacturers follow a somewhat similar approach, consisting of some combination of modifications and adjustments to the carburetor, the distributor vacuum advance, and the engine operating temperature.

A. Review of Retrofit Control Devices

1. Description

The General Motors Emission Control System for used cars contains a thermo-vacuum switch with associated hoses and clamps, sealant and tags for idle adjustment screws, and new specifications for engine operating parameters. The kit specifies an idle mixture adjustment to lower the carbon monoxide content of the exhaust gas, an idle speed increase to promote smooth engine operation, and a timing adjustment to raise the engine operating temperature.

A thermo-vacuum switch is included to make the ignition vacuum advance inoperative during normal operating conditions and operative if the engine tends to overheat.

The Ford Motor Company emission control kit contains a thermo-vacuum switch with associated hardware, new engine operating specifications, and for some six-cylinder engines which were not equipped with centrifugal advance distributors, a new distributor with both vacuum and centrifugal advance modes. Idle and choke settings are changed to reduce carbon monoxide in the exhaust gas, and idle speed is again increased to promote smooth engine operation. Timing is retarded to increase the engine operating temperature, and the thermo-vacuum switch makes the vacuum advance inoperative unless the engine overheats.

The Chrysler Corporation Used-Car Cleaner Air Package contains essentially the same hardware as the GM and Ford kits, except for the addition of leaner main jets in some specific cases. The kit again functions to raise the engine operating temperature, and to reduce carbon monoxide in the exhaust gas. The vacuum advance is made inoperative unless the engine experiences an overheated condition.

2. Availability and Acceptance of Retrofit Emission Control Devices

The General Motors Exhaust Emission Control Kit is designed to fit most domestic passenger cars and light-duty trucks built from 1955 through 1967. The Ford Motor Company and Chrysler Corporation kits are designed strictly for their respective makes of cars through the same production years as previously mentioned.

The General Motors Kit, which offers emission reductions of approximately 50 percent for hydrocarbons, 35 percent for carbon monoxide, and 35 percent for nitrogen oxides is currently offered for sale in all States except California [Ref. 4].

A test marketing program was conducted by General Motors in Phoenix, Arizona last year to determine if customers were willing to purchase the GM kit. Phoenix was chosen for the test market because it was a photochemical smog area and contained an estimated 334,000 cars which were 1967 model year or older that would have been improved by use of the kit, materially reducing automobile pollution in the Phoenix basis.

Despite extensive marketing efforts where it was determined that approximately 90 percent of the potential users were aware of the cost and availability of the kit, only 528 were sold and installed. Less than 1/4 of one percent of the potential users of this particular kit were willing to spend approximately $20 for purchase and installation to control emissions of their older cars [Ref. 5].

This would indicate that some enforcement regulation will probably be required.

3. Cost Factors

Purchase cost will range from $10 to $15 for the three kits that are available.

Installation of the GM and Ford kits may be performed by the individual purchaser with the exception of the adjustment of the CO content in the exhaust gas, for which special equipment is required and which is usually found only at well-equipped commercial garages. To avoid possible mistakes by unskilled and untrained persons, installation of the device at a dealership is recommended. Since the Chrysler kit requires drilling a small hole in the intake manifold, and in some cases replacement of the main jets in the carburetor, installation of the kit by a skilled mechanic is a necessity. Installation time for the GM device is approximately three-quarters of an hour; the Ford device requires one hour, and the Chrysler kit may take from one to two hours. All these suggested installation times are for trained mechanics who are familiar with the installation procedures of the devices [Ref. 2].

Installation costs may range from about $5 to about $15, depending upon which device is involved.

There are no maintenance costs directly associated with the emission control kits themselves. However, for these kits to function properly, the automobile must be in good operating condition. To assure top performance of the emission control device, a complete motor tune-up should be performed on an annual basis. One manufacturer [Ref. 6] reported a decrease in gas mileage of .2 to .3 miles per gallon on a fleet of test cars. The cost per year for this decrease in gasoline mileage would be about $5. It is also reasonable to expect that all kits would cause some decrease in gas mileage due to the removal of the ignition vacuum advance.

The cost of retrofit devices has been estimated for passenger cars and light-duty trucks and does not include heavy-duty motor vehicles over 6,000 pounds.

It has been assumed that due to the simplicity of these devices, they should last the life of the vehicle.

Based on several industry estimates, it is concluded that the average purchase and installation unit cost for retrofit control devices will be approximately $30. In addition, the average annual gas mileage penalty after installation will be about $5 per year.

The national population of vehicles of 1967 model year or older is, of course, steadily declining so that the effectiveness of the retrofit strategy is reduced each year. Table II-3 indicates this anticipated reduction through 1977 based on current vehicles in use by age groups [Ref. 7].

Table II-3.

VEHICLES. 1967 MODEL YEAR OR OLDER

Year	Vehicles In Use	Vehicles 1967 or Older	Percent of Total
1971	93,800,000	54,300,000	58.0
1972	96,800,000	46,500,000	48.0
1973	100,100,000	39,000,000	39.0
1974	103,500,000	32,100,000	31.0
1975	106,900,000	25,600,000	24.0
1976	110,500,000	19,900,000	18.0
1977	114,200,000	14,900,000	13.0

As indicated earlier, it is doubtful that very many retrofit devices will be installed on a voluntary basis. If one percent of the vehicles (1967 or older) in 1971 were to install devices, this cost would be approximately $16,290,000 based on $30 per unit.

If, however, air quality standards and implementation plans so dictate in future years, this cost would be much larger. For example, as implementation plans are developed under the "worst region" concept within each State and these plans become models for other regions within these States, increased population and traffic density in the urban industrialized cities will be important considerations.

Based upon the 1970 Census there are twenty-nine States and the District of Columbia with city populations of over 200,000 people. If the assumption is made that these cities constitute "worst regions" requiring the retrofit strategy and that this requirement is also applicable to all other air pollution control regions within these respective States, then approximately 85 percent of model year 1967 or older vehicles would be required to install retrofit devices. Allowing time for development, approval, and enforcement in these States by 1975, it can be seen from Table II-3 that there will be 25,600,000 vehicles nationally that will be candidates for retrofit devices or about 21,800,000 vehicles in the twenty-nine States and the District of Columbia that would be required by law to have retrofit devices installed. At a unit cost of $30, this would amount to approximately $654,000,000 if enforcement occurred during 1975.

Annual gas mileage penalty of $5 per vehicle per year would amount to $109,000,000 for 1975, $84,500,000 for 1976, and $63,000,000 for 1977 based upon 85 percent of the candidate vehicles as shown in Table II-3.

V. COST ANALYSIS AND SUMMARY

Consumer cost of State vehicle emission inspection programs and associated costs likely to occur as a result of air quality standards and implementation plans in accordance with the 1970 Clean Air Act Amendments are summarized in Table II-4 for the years through 1977.

The analysis and cost estimate are based upon available information as of August 15, 1971.

Autos and light-duty trucks in the 30 jurisdictions likely to be subjected to compulsory emission inspection have been projected through 1977. These projections do not include trucks and buses (gasoline or diesel) with gross weight over 6,000 pounds.

The cost of establishing an emission control program (including equipment) for the entire United States has been estimated at over $100 million [Ref. 8]. For the 85 percent of this national total in the 30 jurisdictions likely to be subjected to compulsory emission inspection through 1977, the cost of capital equipment will be about $85 million. It is assumed that emission testing will be done in the same facility as safety inspection and therefore no land or facility costs have been included.

The estimated cumulative percent of implementation through 1977 shown in Table II-4 becomes the basis for estimating both emission testing and mandatory tune-up on an annual basis. It has been assumed that some type of engine tune-up check, or emission measurement at either idle or with a short dynamometer cycle will be required. Since there is a wide variation of estimated unit test costs for these different procedures, an average cost of $2.00 per test has been used.

In addition, a 30 percent rejection rate from all test procedures has been assumed which will result in a mandatory tune-up for those rejected vehicles. The average cost per tune-up is assumed to be $20 with an offsetting annual savings of $10 resulting from improved gas mileage. Inspection costs are shown increasing annually because vehicle population and the cumulative percent of implementation are both increasing. Pre-1968 vehicles have been projected through 1977 and it has been assumed that retrofit devices will also be required on the same implementation schedule.

Based on several industry estimates, it is concluded that the average purchase and installation unit cost for retrofit control devices will be approximately $30 for pre-1968 model vehicles. Once installed,

Table II-4.

COSTS OF STATE EMISSION INSPECTION PROGRAMS AND ASSOCIATED COSTS
(All costs and number of vehicles shown in millions)

Year	Motor Vehicles 1/	Capital Equipment	Cumulative Percent of Imple-mentation	Emission Testing 2/	Manda-tory Tune up 3/	Pre-1968 Models Vehicles 1/	Retrofit Devices 4/	Gas Mileage Penalty 5/	Annual Totals
1972	82.3	-	-	-	-	39.5	-	-	-
1973	85.1	$ 8.5	10%	$ 17.0	$ 25.5	33.2	$ 99.6	$ 16.6	$ 167.2
1974	87.5	17.0	30%	52.5	78.8	27.1	162.6	40.5	351.4
1975	90.8	34.0	70%	127.1	190.7	21.8	249.6	75.0	676.4
1976	94.0	17.0	90%	169.4	253.8	16.9	101.4	75.0	616.6
1977	97.1	8.5	100%	194.2	291.3	12.6	37.8	63.0	594.8
Totals		$85.0		$560.2	$840.1		$651.0	$270.1	$2,406.4

1/ Vehicles in 30 jurisdictions subject to compulsory regulation (85 percent of projected national total).

2/ Average Test Cost of $2.00.

3/ Thirty percent rejection rate at Average Tune-up Cost of $20 with offsetting annual savings of $10 for gas mileage improvement.

4/ Average cost of $30 includes purchase and installation.

5/ $5 per vehicle per year.

these devices should last the life of the vehicle but will impose a gas mileage penalty of $5 per year.

Table II-4 shows all costs aggregated on an annual basis with totals through 1977.

Other costs that exist but which were not detailed are: inconvenience costs to the motorist, program administration costs, recruitment and training of inspectors, program monitoring, and emission reduction surveillance. The inconvenience cost could certainly be significant considering travel and drivers' time required for inspection. However, the other costs would be relatively small on a per vehicle basis.

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7. Automobile Manufacturers Association, 1970 Automobile Facts and Figures.
8. "Governmental Approaches to Automobile Air Pollution Control." Institute of Public Administration, March 1, 1971.

Appendix III

Assembly Line Testing and Surveillance

I. INTRODUCTION

The purpose of motor vehicle assembly line testing is to insure that motor vehicles as manufactured meet emission standards.

Section 206 of the 1970 Clean Air Act Amendments provides for testing new vehicles or engines being manufactured to determine whether they conform with the regulations prescribed under Section 202 of the 1970 Clean Air Act Amendments.

Assembly line testing is actually a program of quality control and assurance with two essential parts: the control and assurance program carried out by the manufacturers and the surveillance function carried out by EPA.

To achieve meaningful reductions in motor vehicle emissions, controls must be established in the design, manufacture, and operation of these vehicles. These points of control are:

(a) Design--Prototype certification testing.

(b) Manufacture--Assembly line testing and surveillance.

(c) Operation--State inspection programs and retrofit devices.

The following sections are addressed only to control point (b) assembly line testing and surveillance.

II. CURRENT TESTING PRACTICES

The motor vehicle industry has been conducting assembly line testing of vehicles as part of their own in-house quality assurance program. The quantity of production tested is in the range of 1 to 2 percent of the production of the plants where sampling is done [Ref. 1].

The test cycle used by most domestic manufacturers is the Federal 7-mode, 7-cycle test run on a cold-start procedure.

Foreign manufacturers generally check a large portion of their U.S. production for idle CO emission levels and conduct a cold-start Federal emission test on a small sample of the U.S. production.

III. SHORT TEST CYCLES

It is likely that certification tests will continue to require detailed and involved testing procedures which include a large number of modes of operation. However, in both assembly-line testing and State inspection programs, control may be possible with shortened and abbreviated versions of the test cycle and there are many advantages that would result from using the same test for both. Most importantly, if this were done, standards set by various States for in-use testing would produce data comparable to that which would be produced by manufacturers during assembly-line testing.

As a result of studies by manufacturers and independent laboratories, several short tests are now available for appraisal. Procedures associated with the Clayton KEY MODE cycle, the New Jersey ACID cycle, and the General Motors EXIT cycle are potential candidates for assembly-line testing application. (In these short test cycles the vehicle is operated through a predetermined series of operating modes such as acceleration, cruise, deceleration, and idle using a chassis dynamometer. During the test cycle a proportional part of exhaust emissions are continuously collected and analyzed.) However, their approval is contingent upon establishing good correlation with the Federal certification test [Ref. 2].

If this correlation is established, 100 percent assembly-line testing might be feasible using one of these short tests with unit cost in the range of \$20 to \$30 per test.

Despite the technical feasibility of a short test procedure for 100 percent assembly-line testing, current Federal and California exhaust emission test procedures indicate compulsory requirements for longer more comprehensive tests as detailed in Sections IV and V.

IV. FEDERAL TEST PROCEDURE

The Federal test procedures in effect prior to July 2, 1971, were first used to test the 1972 model year vehicles for conformance with the standards. This exhaust emission test was designed to determine mass emissions of exhaust pollutants while simulating an average trip of 7.5 miles in an urban area from a cold start. The test consists of engine startup and vehicle operation on a chassis dynamometer through a specified driving schedule. A proportional part of the exhaust is collected in a bag, and the composite sample is analyzed for the various gases.

As a result of experience with the testing procedures, and based on recent studies of vehicle operational experience, some changes in the procedure have been made to become effective with the 1975 model year testing program. Most of these are technical changes, but one bears mentioning.

Under current test procedures, which had originally been proposed to be applicable to 1975 and 1976 vehicles, the entire test was composed of a single vehicle-run on a dynamometer that begins with the vehicle completely cold. Analysis of vehicle operation data shows that in addition to the usual early morning cold start, vehicles make several hot starts each day. A test procedure was developed that also includes a hot start (which presents special engineering problems to assure that emissions are controlled under these conditions), and that is weighted to reflect the emissions from a car over a 24-hour period (instead of solely during the morning commuter trip as in the present procedure). Analysis of results obtained shows that, for purposes of protecting air quality in the most critical areas, the new test procedure will more accurately weight the cold-start operation of vehicles during the early morning hours.

The new procedure, issued by EPA, and covered in the July 2, 1971, Federal Register, will involve a dynamometer run that will consist of two tests--a "cold" start test begun after the vehicle has been shut off for 12 hours, followed by a "hot" start test begun after the same engine has been turned off for ten minutes following the first cold test. The samples for each test will be collected in separate bags, the contents analyzed, and the results combined in a weighted manner so that the total result to be compared with the standard will consist of 43 percent of the cold-start emissions and 57 percent of the hot-start emissions.

In addition to the final regulations published, there also was published a notice of proposed rule-making that would make the changes in test procedures applicable beginning with the NO_x emission controls for the 1973 model year. These are the same changes that have been finalized for the 1975 model year. It may be noted that, because of the difference in test procedures, there is a necessary revision of the numerical value of the standards. Thus, if the revised test procedures are used beginning in 1973, the numerical value of the carbon monoxide standard will be changed from 39.0 to 28.0 grams per mile, the hydrocarbon standard from 3.4 to 3.0 grams per mile, and the nitrogen oxides standard from 3.0 to 3.1 grams per mile. These do not represent actual changes in the standards, but rather numerical revisions needed to properly relate the standards to the testing and measuring method used [Refs. 3 and 4].

V. CALIFORNIA TEST PROCEDURES

A waiver of Section 209 of the Federal Clean Air Act, as amended, was granted by the Administrator of the Environmental Protection Agency on April 27, 1971, allowing California to enforce motor vehicle emission regulations more stringent than Federal regulations.

California test procedures specify the exhaust emissions testing and reporting requirements for manufacturers of vehicles for sale and registration in the State of California. Two types of tests are required: (a) a short inspection test to be applied to every vehicle before sale, and (b) a quality audit test according to the Official Exhaust Emission Test Procedures for the model year in production.

Manufacturers of limited production vehicles are exempt from the provisions of these procedures.

A vehicle which fails the inspection test may be repaired and, if it passes a retest, may be sold without penalty. Any manufacturer who sells, offers for sale, or attempts to sell a new motor vehicle that fails to meet the inspection standards shall be subject to a civil penalty of five thousand dollars for each such action.

A. Short Inspection Test

1. Applicability

The test procedures are applicable to all manufacturers of gasoline powered light-duty motor vehicles having an engine displacement greater than 50 cubic inches.

The inspection test becomes applicable August 31, 1971, beginning with the 1972 model year vehicles to be sold in California, and the penalty provisions of this procedure become effective with the 1973 model year vehicles.

At least 25 percent of the vehicles of each engine size produced during 1972 model year will be subject to the inspection procedures. These vehicles shall be randomly selected as far as practical from representative equipment combinations (i.e., exhaust control systems, transmissions, carburetor, and air conditioners) in proportion to production for sale in California.

All vehicles for the 1973 model and subsequent years will be subject to the inspection procedure.

2. Emission Standards

Exhaust emission standards for the 1972-73 model year assembly-line test are:

1.4 grams per mile hydrocarbons,
19.0 grams per mile carbon monoxide,
3.2 grams per mile oxides of nitrogen.

3. Inspection Test Procedures

The inspection test for the 1972 model year shall comprise one hot 7-mode cycle as specified in the "California Exhaust Emission Standards and Test Procedures for 1971 and Subsequent Model Gasoline-Powered Motor Vehicles under 6,001 Pounds Gross Vehicle Weight."

Instrumentation equivalent to that specified in the "California Exhaust Emission Standards and Test Procedures for 1971 and Subsequent Model Gasoline-Powered Motor Vehicle under 6,001 Pounds Gross Vehicle Weight" shall be used. Preconditioning or warm-up of the engine shall approach, as closely as practical, official procedure 6th cycle conditions. Variations from the above procedure which produce equivalent results may be authorized by the Executive Officer and reported to the Board. For 1973 and subsequent model years, the inspection test procedure shall be the same as for 1972. If a new exhaust control system is introduced in which the relationship between hot- and cold-start emissions is markedly different from current systems, alternative appropriate procedures may be approved by the Executive Officer and reported to the Board.

B. Quality Audit Test (Assembly-Line Testing)

1. Applicability

This procedure is applicable, beginning July 1, 1971, to all manufacturers of gasoline-powered, light-duty motor vehicles having an engine displacement greater than 50 cubic inches. Any vehicle manufactured for sale in California in quantities of less than 1,000 units per year will be exempt from the quality audit test procedure.

2. Test Procedure

The sampling and analytical procedure shall be that described in the Official California Exhaust Emission Test Procedure for the model year in production, with the specific exceptions stated as follows:

(a) The evaporative emission control system may be disconnected during the test.

(b) The engine shall be adjusted to the manufacturer's specifications for delivery to customers.

(c) For the 1972 model year only, the Quality Audit tests may be performed by the 7-mode, 7-cycle Test Procedure or the optional Constant Volume Sampling (CVS) procedure or a combination thereof.

3. Vehicle Sample Selection

The number of vehicles in the sample shall be not less than two percent of each engine displacement size. They shall be equipped with exhaust controls as for California and shall be representative of at least 80 percent of each manufacturer's total California sales of each engine-size category. Vehicles shall be selected that are equipped with exhaust control systems, transmissions, carburetors, and air conditioners in proportion to production for California, and shall be randomly selected as far as practical.

C. Access for California Air Resources Board Personnel

Air Resources Board personnel and mobile laboratories shall have access to vehicle assembly plants or distribution facilities for the purpose of vehicle selection, testing, and observation. The frequency of access shall be proportional among manufacturers in relation to California vehicle sales, as far as practical. Scheduling of access shall be arranged with the plant or facility manager and shall not unreasonably disturb normal operations [Ref. 5].

VI. EPA SURVEILLANCE

It is assumed that automobile manufacturers, both foreign and domestic, will conduct their own quality control and assurance work to determine that they are in compliance with emission standards. EPA's staff will approve the test methods and procedures, set standards, and monitor the assembly lines by independently selected samples and tests in addition to auditing test data from the manufacturer. (In addition, for California automobiles only, the California Air Resources Board will have access to vehicle assembly plants or distribution facilities for the purpose of vehicle selection, testing, and observation.)

Although surveillance might be achieved using mobile test vans, which would visit final assembly and major unloading points of foreign imports on a monthly basis, it is probable that the monitoring program will require at least one full-time EPA representative at each major assembly plant for the first year or so. After procedures are implemented and working properly, the number of field representatives may be reduced. The total cost, including equipment and support, has been estimated at approximately $5 million annually [Ref. 2].

EPA may assume another vital role in monitoring the assembly-line testing--namely, making sure that accrued costs of testing are not inflated when they are passed on to the purchaser of the automobile. The modest increase in cost to the purchaser should be sufficient to take care of the testing operation alone. In connection with EPA's overall objectives, it is important that these costs are not utilized as an excuse for increases in automobile costs.

Since cost estimates are only estimates based on the best information available, one objective of monitoring should be to provide better cost figures and to maintain and abate the actual costs found to accrue under the assembly-line testing program.

VII. COST ANALYSIS AND SUMMARY

Consumer cost of assembly-line testing of vehicles as a result of California and Federal regulations, compulsory in 1972 and 1973 respectively, and associated EPA surveillance costs have been summarized in Table III-1 for the years through 1977.

The analysis and cost estimates are based upon available information as of August 15, 1971.

The cost of assembly-line testing done voluntarily by auto manufacturers prior to these compulsory dates and the cost of engine certification testing are not included.

Domestic automobile and light-duty vehicle production plus net automobile and light-duty vehicle imports have been projected for 1972 through 1977 [Ref. 6].

No testing costs have been included for trucks and buses (gasoline or diesel) with gross vehicle weight over 6,000 pounds.

Beginning with the 1972 model year vehicles, California will require assembly-line testing (quality audit test) on 2 percent of those vehicles sold in California. In addition, a short inspection test will be required for 25 percent of the vehicles sold in California. These requirements are described in Section V. For 1973 model year vehicles, California will require 100 percent of the vehicles sold in California to have a short inspection test. The unit cost of this short inspection test has been estimated at $40. Compulsory Federal assembly-line testing will include vehicles sold in California in 1973 and subsequent years.

California-bound vehicles represent between 7 and 8 percent of the national total [Ref. 6].

Table III-1.

ASSEMBLY-LINE TESTING AND ASSOCIATED COSTS

Year	Domestic Motor Vehicle[1] Production Plus Net Imports	Assembly[2] Line Testing	California[4] Automobiles	California[5] Inspection Test	EPA Surveillance	Annual Totals
1972	11,400,000	$ 2,500,000[3]	835,000	$ 8,350,000[6]	$ 5,000,000[7]	$ 15,850,000
1973	11,600,000	34,800,000	850,000	34,000,000	5,000,000	73,800,000
1974	11,800,000	35,400,000	865,000	34,600,000	5,000,000	75,000,000
1975	12,100,000	36,300,000	880,000	35,200,000	5,000,000	76,500,000
1976	12,300,000	36,900,000	900,000	36,000,000	5,000,000	77,900,000
1977	12,600,000	37,800,000	920,000	36,800,000	5,000,000	79,600,000
Totals		$183,700,000		$184,950,000	$30,000,000	$398,650,000

[1] 1970 Ward's Automotive Yearbook (Autos and light-duty trucks).

[2] Assume 3 percent of production at $100 per test--Avg. $3/car.

[3] Required for California vehicles.

[4] 7.33 percent of National Production.

[5] Hot Seven-Mode Cycle Test $40/car.

[6] Twenty-five percent testing for 1972, then 100 percent testing.

[7] Provides startup time in advance of 1973.

Federal compulsory assembly-line testing will begin with the 1973 model year. The exhaust emission test was designed to determine mass emissions of exhaust pollutants while simulating an average trip of 7.5 miles in an urban area from a cold start using a chassis dynamometer as described in Section IV. This test procedure is also specified for 1974 model year.

Beginning with 1975 model year, a new test procedure, also described in Section IV, will involve a cold start followed by a hot start using a dynamometer and similar exhaust sampling techniques. This new test procedure is also specified for 1976 model year as set out by the July 2, 1971, Federal Register. It is assumed that this same test procedure will remain in effect for 1977 model year.

The unit cost for both assembly-line testing procedures has been assumed at $100. This would make it appear that 100 percent testing would not be feasible because the annual cost would exceed $1 billion annually. However, no EPA sampling guidelines have been issued for these tests.

Although a variable sampling rate dependent upon the number of vehicles meeting the emission standards may be feasible, a fixed 3 percent sampling rate has been assumed for all model cars through 1977 including those to be tested for California in 1972.

The cost of EPA surveillance has been estimated at $5 million per year, assuming representatives at each major assembly plant rather than the use of mobile test vans. EPA surveillance is described in Section VI.

Table III-1 shows all costs aggregated on an annual basis with totals for the period of 1972 through 1977.

VIII. REFERENCES

1. Report on Assembly Line Emission Testing of Motor Vehicles. NAPCA, Bureau of Abatement and Control, April 8, 1970.

2. Motor Vehicle Assembly-Line Testing. Final Report prepared by Research Triangle Institute for the National Air Pollution Control Administration, July 1970.

3. "Exhaust Emission Standards and Test Procedures." EPA. Federal Register, Part II, Volume 36, Number 128, July 2, 1971.

4. Environmental News. EPA. June 30, 1971.

5. California Assembly-Line Test Procedures. Adopted September 16, 1970, Amended February 17, 1971, California Air Resources Board.

6. 1970 Ward's Automotive Yearbook.